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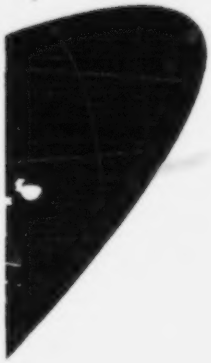

DEFENCE DÉFENSE

Fibre Optic Transmitter/Receiver Selection Guide

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Contract #W7707-99759/001/HAL

Scientific Authority Ken Rhyno

The scientific or technical validity of this Contract Report is entirely the responsibility of the contactor and the contents do not necessarily have the approval or endorsement of Defence R&D Canada

Defence R&D Canada

Contractor Report
DREA CR 2001-133
October 2001

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Defence Research Establishment Atlantic

Contractor Report

DREA CR 2001-133

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Abstract

This report provides a selection guide and specification charts for the selection of fibre optic transmitters and receivers for digital telemetry between the Fibre Optic Array Module (FOAM) and Fibre Optic Receive Unit (FORU) of TIAPS. A total of five fibre optic paths (5 X 62.5/125μm multimode fibre) transmit data from the two receive arrays to receive hardware on the ship. Data rates are expected to be between 25 and 50 Mbps. Selection of appropriate fibre optic transmitters and receivers requires consideration of environmental, electrical, optical, and mechanical specifications of the devices, as well as general system design guidelines for fibre optic telemetry.

Résumé

Ce rapport renferme un guide de sélection et des tableaux de spécifications permettant de choisir des émetteurs et récepteurs à fibres optiques qui puissent assurer la télémesure numérique entre le module de réseau à fibres optiques (FOAM) et le bloc de réception à fibres optiques (FORU) du TIAPS. Un total de cinq chemins à fibres optiques (5 X fibres multimodes de 62.5/125 μm) permet de transmettre des données des deux réseaux de réception au matériel de réception du navire. Les débits de données attendus se situent entre 25 et 50 Mbit/s. La sélection des émetteurs et récepteurs à fibres optiques appropriés exige l'examen des spécifications environnementales, électriques, optiques et mécaniques des dispositifs, ainsi que des lignes directrices générales de conception de systèmes applicables à la télémesure par fibres optiques.

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Executive summary

DREA is in the process of developing a fibre optic based data telemetry link between the towed array modules and the array receivers aboard ship. The Fibre Optic Array Modules (FOAM), together with the Fibre Optic Receive Unit (FORU), forms the ends of a digital data transmission system from sensor arrays in the TIAPS system to receive hardware on the ship. The two sensor arrays generate bit streams with bit rates in excess of 32 Mbits/sec. There are a total of five paths available for optical transmission.

DREA requires analysis and recommendation of appropriate fibre optic transmitters and receivers; the development of a test plan and procedures to qualify optical transmitters and receivers; and contractor support in printed circuit board design.

This report provides a selection guide and specification charts for the selection of fibre optic transmitters and receivers appropriate for the digital telemetry between the Fibre Optic Array Module (FOAM) and Fibre Optic Receive Unit (FORU) of TIAPS. Selection of appropriate fibre optic transmitters and receivers requires consideration of environmental, electrical optical, and mechanical specifications of the devices, as well as general system design guidelines for fibre optic telemetry. These design issues are defined and their importance is explained in this report.

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Sommaire

Le CRDA développe actuellement une liaison de télémesure de données à fibres optiques entre les modules de réseau remorqué et les récepteurs de réseau embarqués à bord du navire. Avec le bloc de réception à fibres optiques (FORU), les modules de réseau à fibres optiques (FOAM) constituent les extrémités d'un système de transmission de données numériques, entre les réseaux capteurs du TIAPS et le matériel de réception du navire. Les deux réseaux capteurs produisent des flux binaires dont le débit dépasse 32 Mbit/s. Au total, cinq chemins sont disponibles pour la transmission optique.

Le CRDA a besoin d'une analyse et d'une recommandation portant sur les émetteurs et récepteurs à fibres optiques appropriés, de l'établissement d'un plan et de procédures d'essai servant à évaluer les émetteurs et les récepteurs optiques, ainsi que du soutien d'un entrepreneur pour la conception de cartes de circuit imprimé.

Ce rapport renferme un guide de sélection et des tableaux de spécifications permettant de choisir des émetteurs et récepteurs à fibres optiques qui puissent assurer la télémesure numérique entre le module de réseau à fibres optiques (FOAM) et le bloc de réception à fibres optiques (FORU) du TIAPS. La sélection des émetteurs et récepteurs à fibres optiques appropriés exige l'examen des spécifications environnementales, électriques, optiques et mécaniques des dispositifs, ainsi que des lignes directrices générales de conception de systèmes applicables à la télémesure par fibres optiques. Les questions de conception sont définies et leur importance est expliquée dans ce rapport.

Lowery-Simpson, Murray et MacKay, Ian 2001
Fibre Optic Transmitter/Receiver Selection Guide
DREA CR 2001-133
Centre de recherches pour la défense Atlantique

FIBRE OPTIC TRANSMITTER/RECEIVER SELECTION GUIDE

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June 30, 2000

FOCAL
A KAYDON COMPANY

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LIST OF ACRONYMS AND TERMINOLOGY

ADM	Acoustic Data Module
BER	Bit Error Rate
COTS	Commercial Off-The-Shelf
DFB	Distributed Feedback (laser)
DREA	Defence Research Establishment Atlantic
DUT	Device Under Test
ECL	Emitter-Coupled Logic
ESD	Electro-Static Discharge
FOAM	Fibre Optic Array Module
FODA	Fibre Optic Demonstration Array
FORU	Fibre Optic Receive Unit
FORJ	Fibre Optic Rotary Joint
ITU-T	International Telecommunication Union - Telecommunication standardization sector of ITU
LED	Light Emitting Diode
LDI	Laser Diode Inc.
MFB	Minimum Flux Budget
MLM	Multi-Longitudinal Mode (laser)
MTBF	Mean Time Before Failure
OCP	Optical Communication Products (Inc.)
ORL	Optical Return Loss
PECL	Positive Emitter-Coupled Logic
RMS	Root Mean Squared
RX	Receiver
SDH	Synchronous Digital Hierarchy (similar to SONET)
SLM	Single Longitudinal Mode (laser)
SONET	Synchronous Optical Network
STM	Synchronous Transport Module
TDM	Time-Division Multiplexer / Multiplexing
TX	Transmitter
WDM	Wavelength Division Multiplexer / Multiplexing

1.0 INTRODUCTION

This document serves as a fibre optic transmitter/receiver selection guide for Defence Research Establishment Atlantic contract W7707-9-7591, issued 2000-04-03. Herein are described the selection guidelines and criteria for fibre optic transmitters and receivers suitable for use with FOAM and other towed array telemetry modules.

1.1 Overview Of Work Undertaken For FOAM Contract

Work was undertaken by Focal Technologies Corp. at the request of DREA to provide analysis and recommendation of appropriate fibre optic transmitters and receivers for FOAM, and a test plan with procedures to qualify optical transmitters and receivers. Eight fibre optic transmitter/receiver pairs from six different manufacturers were identified as candidates and compared on the basis of their suitability for various environmental, optical, electrical, and other requirements outlined by both DREA and Focal. The specifications of the devices are provided in several detailed charts. A chart at the end of the report summarizes the critical and beneficial non-critical requirements that identify the best candidate devices for inclusion in the FOAM system.

General information on fibre optic telemetry systems is provided in the appendices, and includes fibre optic device data sheets, application notes, quality test reports, optical system design guidelines, sample circuits, and sample layouts.

1.2 Previous Contracts

Table 1 summarizes the history of Focal Technologies' involvement in DREA contracts.

Table 1 - Past DREA Contracts

Contract	Completion	Components	Topologies	Result / Conclusion
Data Multiplexing in Umbilicals	November 1984	WDM, TX/RX, Connectors, Encoding, Laser Diodes, Integrated Optics	Star, Ring, Bus with TDM and WDM	Implementation was component limited
Distributed Sensor Telemetry	August 1985	Multimode device hardware evaluation, Bench demo of a 2 channel WDM system	As above	Ready for sea trial
1986 Wet Test and Ongoing Evaluation	June 1987	As above plus ITT Cannon D*M 8 way optical connector; hybrid tow cable purchased	Point-to-point, aft telemetry module to ship	Good optical margins but no useful acoustic data due to power line noise problems; connector mating difficult
Multipass Fibre Optic Rotary Joint (FORJ)	March 1987	FORJ	Winch interface	4 way FORJ with electrical slip delivered
1988 Dry Test	March 1989	LED transmitters, PIN receivers, WDM, FORJ, Manchester encoding, ITT D*M connectors	WDM star, TDM ring in forward and aft telemetry modules	Successful with minor electrical problems
Hybrid Coupler	March 1992	Hybrid 3-202 in-line coupler		Conceptual design developed and tested, production version suspect
Optical Switching Assessment	October 1991	Integrated optic and other photonic switches	Linear bus and active star	Optical switching not necessary for other than optical hydrophones; 2 contemporary telemetry schemes demonstrated
Fibre Optic Demonstration Array (FODA)	August 1996	Complete, fieldable optical telemetry demonstration and test system including updated hybrid coupler	Point-to-point	Ready for sea trial 3 Sept. 1996

2.0 FOAM FUNCTIONAL REQUIREMENTS

The following sections detail performance requirements for the transmitters and receivers, defined by DREA and Focal. Critical requirements identified in the charts must be met, or be capable of being met, by the devices finally selected. Non-critical requirements are desirable but not necessary for final selection. General requirements defined by DREA in the Statement of Work were an optical flux budget of 25 dB, ECL interface circuitry (later defined as differential ECL), ADM-2 environmental specifications, and a single transmitter and receiver design capable of operating in different modules.

2.1 Environmental Requirements

Fibre optic transmitters and receivers used in the FOAM system could potentially be exposed to a wide range of temperatures, humidity, pressures, and other environmental extremes typical of a marine application. The FOAM system is required to meet the environmental specifications outlined in Table 2.

Table 2 - Environmental Requirements

Parameter	Definition	Requirement
Operating Temperature*	The temperature range over which the transmitter or receiver can be operated while still maintaining acceptable output power levels, receiver sensitivities, bit-error rates, etc.	-40 to +70 °C
Storage Temperature*	The temperature range over which the device may be stored while not in use.	-40 to +70 °C
Ambient Pressure Rating	The maximum pressure level of the surrounding medium (typically air or oil) at which the device will continue to operate properly.	Up to 200 bar
Shock Rating*	The shock level for which the device has been successfully tested.	Can be dropped from 1 m height
Vibration Rating*	The vibration level for which the device has been successfully tested.	MIL-STD-167-1
Solvent Sensitivity	Types of solvents or other media which could affect the appearance or operation of the device.	Not sensitive to hydrocarbons (e.g. Bayol 35)
Transportability*	The ability of the device to be transported by air, rail, truck, barge, or ship with no degradation of components.	Air, rail, truck, barge, or ship
Safety	Any considerations which must be taken into account when using or handling the device. Class I lasers are preferred to minimize risk of eye injury.	Must not injure personnel or equipment
Humidity*	The range of relative humidity (non-condensing) over which the device will operate properly.	Must work in a marine environment. Up to 85 % R.H.

Note: Asterisks in the above table denote critical specification requirements.

2.2 Optical Requirements

DREA has specified the range of data rates for the fibre optic transmitter/receiver pairs in FOAM as 25 Mbps to 50 Mbps, and has also specified that each link have a minimum flux budget (MFB) of 25 dB. In addition to these requirements, Focal has specified other parameters, based on the company's experience with optical devices and the ITU-T G.957 and G.958 SDH recommendations, similar to SONET requirements. An operational wavelength of 1310 nm is specified to minimize power loss in the fibre and optimize it's bandwidth while supporting an upgrade to singlemode fibre. All requirements and optical parameters are listed in Table 3.

Table 3 - Optical Requirements

Parameter	Definition	Requirement
Output Power*	The laser's (or LED's) light output as measured in dBm, and typically expressed in terms of a minimum, average, and maximum value over the entire operating temperature range of the device.	Focal: -5 dBm
Sensitivity to Back Reflection	Refers to the transmitter's susceptibility to back reflected light, and is expressed as a minimum back reflection or optical return loss (ORL) value in dB. The system ORL must be greater than the specified ORL for the transmitter for it to work at its stated bit-error rate.	Not Sensitive Focal: 25 dB ORL
Min. Bit Rate Supported*	Refers to the minimum ECL data rate which can be input to the transmitter, or received from the receiver.	25 Mbps
Max. Bit Rate Supported*	Refers to the maximum ECL data rate which can be input to the transmitter, or received from the receiver.	50 Mbps
Wavelengths Available	A list of all the wavelengths supported by a given transmitter or receiver. Transmitters have a specified wavelength; most receivers support a band of wavelengths, e.g. 1200-1600 nm.	None Focal: 1310 nm for multimode
Spectral Width	Refers to the RMS spectral width of the transmitter output for multi-longitudinal mode lasers (MLMs) and the Gaussian spectral width of single longitudinal mode lasers (SLMs). Larger spectral widths proportionally increase chromatic dispersion, reducing available flux budget as a "dispersion penalty".	Focal: <= 4 nm
Output Power Stability	The stability of a transmitter's optical output power over its entire operating temperature range, expressed in dB (e.g. +/-1.0 dB).	Not Specified
Optical Rise Time	The time required for the transmitter power level to go from 20% to 80% of its full-scale value for a logic '0' to '1' transition.	Not Specified
Optical Fall Time	The time required for the transmitter power level to go from 80% to 20% of its full-scale value for a logic '1' to '0' transition.	Not Specified

Parameter	Definition	Requirement
Jitter	Refers to the time interval deviation between consecutive edges of the transmitter output data (for an alternating bit pattern) and/or the time interval deviation between consecutive edges of the differential ECL output from the receiver. It can be expressed as either a maximum or a typical value.	Not Specified
Extinction Ratio	The optical power ratio between the transmitter's on (logic '1') and off (logic '0') states.	Not Specified
Power Monitoring*	Refers to the ability of the transmitter or receiver to monitor the power of light transmitted or received respectively.	Monitor receiver power (analogue)
Receiver Sensitivity	The minimum light level (over all operating temperatures) at which the receiver will continue to operate within its stated bit error rate limit. The lower limit of this range is the Receiver Sensitivity (see above).	Focal: < -30 dBm
Receiver Dynamic Range	The range of receiver input power levels over which the receiver will continue to operate within its stated bit error rate limit. The lower limit of this range is the Receiver Sensitivity (see above).	25 dB minimum flux budget (MFB)
Damage Threshold	The input power of light for which the receiver could potentially become damaged.	Not Specified

Note: Asterisks in the above table denote critical specification requirements.

2.3 Electrical Requirements

Electrical requirements stipulated by DREA for the FOAM system were differential ECL inputs and outputs. Other parameters of interest were the voltage supplies required, maximum current, power requirements, over-voltage or ESD protection, and the range of data duty cycles over which the devices could be used. (See Table 4.)

Table 4 - Electrical Requirements

Parameter	Definition	Requirement
Voltages	The power supply voltages required for the transmitter or receiver.	Not Specified
Current Levels	The maximum current levels for each of the power supply voltages.	Not Specified
Power Levels	The maximum electrical power requirement for either the transmitter or receiver.	Not Specified
Sensitivity to Voltage Fluctuations	Refers to the operating voltage range for each of the power supply voltages. It also includes any requirements for voltage ripple within this range.	Not Specified
Data Formats Supported *	The types of ECL formats supported (i.e. differential or single, PECL, ECL, etc.)	Differential ECL
Over-Voltage Protection	Refers to any protection circuitry that the transmitter or receiver might have built-in to protect against ESD or incorrect circuit connections.	Not Specified
Data Duty Cycle Range	The range of acceptable duty cycles for input ECL data to the transmitter. ECL data with a duty cycle outside this range could cause the average output power of the transmitter to drift with time.	Not Specified

Note: Asterisks in the above table denote critical specification requirements.

2.4 Other Requirements

Table 5 lists the other requirements (such as packaging, connector, and fibre options) which must be considered when choosing a suitable fibre optic transmitter/receiver pair.

Table 5 - Other Requirements

Parameter	Definition	Requirement
Packaging	Describes the type of housing used for the transmitter or receiver, the number of pins, and the dimensions of the transmitter or receiver (not including any fibre pigtails).	Must fit within a 2" diameter can.
Fibre Types Supported *	Specifies whether or not the transmitter and receiver support singlemode and / or multimode types of optical fibre.	Multimode, 62.5 / 125 µm Graded Index
Fibre Interface Types and Connection Options	Describes what types of pigtails and bushings are available on the transmitters and receivers.	Not specified
Mean Time Before Failure	The average length of time required for the device to fail. It may be expressed as a guaranteed life span or a probable life span under adverse operating conditions (ex: at least 5000 hours at 85 °C).	Not specified
Price	The price for a specified quantity of transmitters and receivers.	Not specified

Note: Asterisks in the above table denote critical specification requirements.

3.0 FIBRE OPTIC DEVICE SPECIFICATIONS

3.1 Manufacturers Included In Report

For detailed information on the manufacturers whose products are analysed in this report, see Appendix B.4. Although COTS transmitter and receiver modules are widely available from a number of manufacturers, particularly for SONET applications, devices from a select group of North American manufacturers were chosen for consideration in this report as a representative sample of the range of performance available. Focal Technologies has had direct experience with fibre optic products of the candidate suppliers through development of its Model 903 video/data multiplexers for ROVs.

All of the transmitters described here are semiconductor lasers, with the exception of Laser Diode Inc.'s ruggedized transmitter module and Agilent's HFBR-1312T transmitter, which both use LEDs.

3.2 Table Of Manufacturer Specifications

Tables 6 through 10 on the following pages provide a comprehensive assessment of the various transmitter/receiver device specifications. Also included as references are the FOAM/ADM-2 requirements, listed in the first row of each of the tables, and the ITU-T G.957 and G.958 Recommendations For Digital Sections And Digital Line Systems (SDH) listed in the second row of tables 7 and 8.

3.3 Discussion Of Specifications

Reliability is a primary concern for any system-critical military application, such as FOAM, particularly where systems are operated remotely and require lengthy deployments in a sealed environment. Many of the specifications, such as operating temperature and transmitter output power, represent critical requirements needed to maximize system reliability.

The 25 dB flux budget requirement significantly favours lasers over LEDs for the transmitters. Lasers are also capable of higher data rates — up to 10 Gbps — than LEDs, which are typically limited to under 150 Mbps. Although FOAM's current bit rate requirements may be met by LEDs, future upgrades might not be supported. Laser modules used for SONET applications are particularly suitable for an upgrade path, since the readily available modules support data rate ranges centered on a series of nominal data rates from roughly 52 Mbps (OC-1) to 2.5 Gbps (OC-48) and beyond. As long as the associated electrical circuits support higher data rates, the pin compatible SONET modules may simply be replaced with faster versions to upgrade the system.

Several of the devices analysed failed to meet critical specifications. The FORCE Model 2666 transmitter / receiver and the FORCE Model 2753 transmitter / receiver are not specified for the full temperature range of -40°C to +70°C, and the Model 2666 has a minimum flux budget (MFB) of only 18 dB, which is less than the required MFB of 25 dB. The LDI ruggedized transmitter module has a typical output power of only -16 dBm which is well short of the required -5 dBm, and has an MFB of only 11 dB.

Agilent's HFBR-1312T transmitter also has a lower than required output power of only -17.5 dB (min). This is partly offset by the very low minimum receiver sensitivity of -38.5 dBm for the HFBR-2316, its corresponding receiver. The MFB is 21 dB for this LED-based system is still insufficient to meet the 25 dB requirement. LED devices are generally smaller in size than laser modules, lower in price by almost an order of magnitude, and usually have better environmental specifications. Their speed and especially power limitations, however, make them unsuitable for FOAM.

Neither pressure compatibility data nor transportation test results are available for any of the transmitters or receivers reviewed in this report. A number of the manufacturers (Lucent, Nortel, OCP, and Agilent) claim shock and vibration test results to the MIL-STD-883 specification (Methods 2002 and 2007 respectively). These qualifications, along with the ability of these devices to function over the -40°C to +85°C temperature range, implies suitability for most types of transportation. The lack of pressure testing data on any devices, and their intended applications, leads to the requirement for a protective cannister around the transmitter, receiver, and any supporting electronics.

Lucent, Nortel, and OCP devices claim virtually identical performance ratings and other specifications. All of these devices are specified over the -40°C to +85°C temperature range, have been tested for shock and vibration, are class I laser devices, and function for relative humidity up to 95%. The Nortel devices are the only ones with results for solvent sensitivity tests (MIL-STD-883 Method 2015), although OCP claimed that their devices were insensitive to solvents due to their metal packaging. For any of the devices, however, care must be taken to ensure that the fibres and other non-metallic components such as the rubber strain-relief boots do not come into contact with hydrocarbon fluids like Bayol 35, which act as plasticizers.

The Lucent, Nortel, and OCP transmitters all have power outputs greater than -5 dBm, and MFB's greater than 33 dB. (Less expensive transmitter versins are available from each manufacture with power outputs less than -5 dBm, but still enough to maintain a 25 dB minimum flux budget.) They also all have the ability to monitor optical power levels at both the transmitter and receiver. Both the Lucent and Nortel devices have over-voltage protection built in; the OCP devices do not. The Lucent receiver requires a conversion stage to be added in order to convert output signals from PECL to ECL. The Nortel devices also require additional circuitry.

The Lucent and OCP devices, being SONET modules, have nearly the same dimensions (0.4"x0.6"x1.3"); the Nortel devices were a bit smaller (0.4"x0.3"x0.5") although their additional circuitry requirement would make their final module size similar to Lucent's and OCP's. Nortel's devices are the least expensive, but the cost of the additional components and labour required to complete the modules would have to be taken into account. Lucent and OCP receivers were similarly priced between US$200 and US$300 per unit; OCP transmitters were significantly more expensive at US$459 per unit compared to only US$259 per unit for the Lucent transmitters.

Several of the receivers use 50 μm core fibre pigtails. Mating a 50/125 μm receiver pigtail with the 62.5/125 μm fibre used in the FOAM system should not cause any significant problems other than a small power loss (typically 1-2 dB for short receiver pigtails) and perhaps an increase in back reflection.

For maximum overall performance and upgradeability, any one of the Lucent, Nortel, or OCP laser transmitters and receivers could be chosen for the FOAM system. For higher data rates, however, the minimum flux budgets of the transmitter/receiver pairs decline, as shown in Figure 1 below.

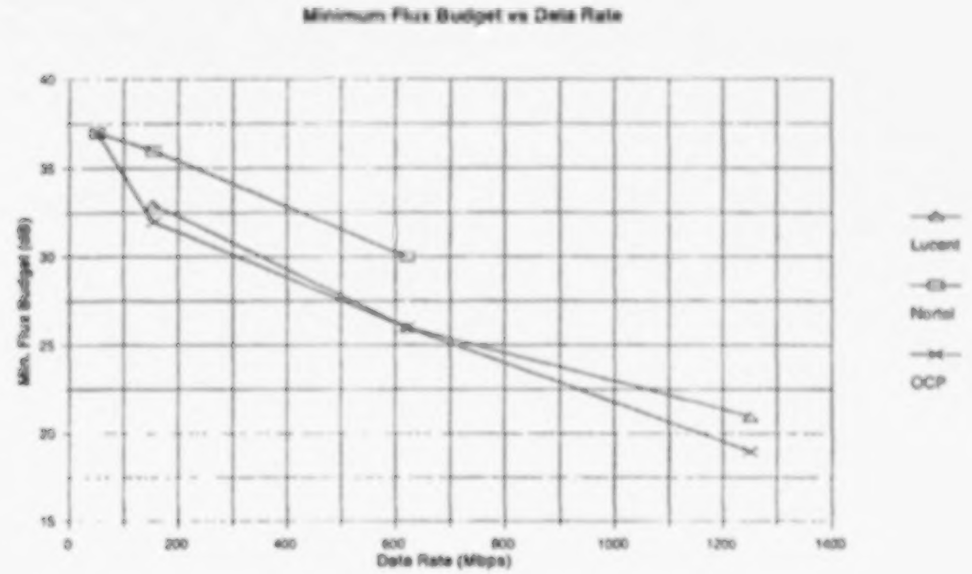

Figure 1 - Minimum Flux Budget (MFB) vs data rate for Lucent, Nortel, and OCP transmitters and receivers.

Table 6 - Environmental Specifications

TX / RX Manufacturer	Operating Temp. (°C)	Storage Temp. (°C)	Ambient Pressure Rating	Shock Rating	Vibration Rating	Solvent Sensitivity	Transport-ability	Safety	Humidity
1. FOAM/ADM-2 Requirement	-40 to +70	-40 to +70	Up to 200 bar	Can be dropped from 1 m height	MIL-STD-167-1	Not sensitive to hydro-carbons (Bayol 35)	Air, rail, truck, barge, or ship	Must not injure personnel or equipment	Must work in a marine env. Up to 85% R.H.
2. FORCE Model 2666 TX & RX	-10 to +55[1]	-20 to +70	Not known (not hermet. sealed)	System-level testing by customers	System level testing by customers	System-level testing by customers	System level testing by customers	Class IIIb laser product	System level testing by customers
3. FORCE Model 2753 TX & RX	-20 to +60	-40 to +100	Not known (not hermet. sealed)	System-level testing by customers	System level testing by customers	System-level testing by customers	System level testing by customers	Class IIIb laser product	0 to 95% R.H. non-condensing
4. LDI Airpak TX & RX	-40 to +85[2]	-40 to +85	See Note 3	See Note 3	See Note 3	See Note 3	See Note 3	Class IIIb laser product	See Note 3
5. LDI Ruggedized TX & RX	-40 to +85	-40 to +85	Not known[4]	MIL-STD-883 Method 2002	Not known[4]	MIL-STD-883 Method 2015	Not known[4]	N.A. (LED source)	Not known[4]
6. Lucent 1241 & 1340 TX & RX	-40 to +85	-40 to +85	Not known (not hermet. sealed)	MIL-STD-883 Method 2002	MIL-STD-883 Method 2007	Not herm. sealed. Do not spray or immerse in cleaning solvents	Not tested	Class I laser product	0 to 95 % R.H. non-condensing
7. Nortel LCV75 TX PTAV622 RX	-40 to +85	-40 to +85	Not known	MIL-STD-883 Method 2002	MIL-STD-883 Method 2007	MIL-STD-883 Method 2015	Not tested	Class I laser product	Up to 95 % R.H. non-condensing
8. OCP STX / SRX TX & RX	-40 to +85	-40 to +85	Not known	MIL-STD-883 Method 2002	MIL-STD-883 Method 2007	Not sensitive, TX and RX are housed in a metal package.	Not tested	Class I laser product	Up to 85 % R.H.

TX / RX Manufacturer	Operating Temp. (°C)	Storage Temp. (°C)	Ambient Pressure Rating	Shock Rating	Vibration Rating	Solvent Sensitivity	Transport-ability	Safety	Humidity
9. Agilent Technologies HFBR-1312T Transmitter HFBR-2316T Receiver	-40 to +85	-50 to +85	Not known	MIL-STD-883 Method 2002 Condition B	MIL-STD-883 Method 2007 Condition A	Do not use halogenated hydro-carbons. Tested to MIL-STD-883 Method 2015	Not tested	N.A. (LED source) See Agilent Technologies App. Note 1109. Appendix A.2	Up to 85% at 85 °C

1. Case operating temperature is +5 °C to +50 °C.
2. The temperature range of -40 °C to +85 °C is only valid for the 1310 nm transmitter, the 1310 nm receiver and the 1550 nm receiver. The operating temperature range for the 1550 nm transmitter is 0 °C to +65 °C.
3. The LDI Airpak transmitter and receiver use an open-package type design and are not suitable for stringent environmental requirements.
4. The specified parameter has not been tested, but can be tested by LDI for a fee.

Table 7 - Optical Specifications

TX / RX Manufacturer	TX Output Power	RX Sensitivity	RX Dynamic Range	Power Monitoring	Min. Bit Rate Supported	Max. Bit Rate Supported	Wavelengths Available	Spectral Width
1. FOAM/ADM-2 Requirement	Not specified Focal: -5 dBm	Not specified Focal: -30 dBm	25 dB flux budget	TX: Optional RX: Monitor RX power.	25 Mbps	50 Mbps	Not specified Focal: 1310nm	Not specified
2. ITU-T Recommend-ations G.957 and G.958[10]	Short haul[9]: -8 dBm (max) -15 dBm (min) Long haul[9]: 0 dBm (max) -5 dBm (min)	Short haul[9] (<= 2Km) -23 dBm (<=15 Km) -28 dBm Long haul[9] -34 dBm	Attenuation range = 0 to 12 dB for short haul[9] = 10 to 28 dB for long haul[9]	Able to monitor degradation of TX and loss of incoming signal at RX.	155 Mbps nominal for STM-1 (SONET OC-3 equivalent)	155 Mbps nominal for STM-1 (SONET OC-3 equivalent)	1310 nm 1550 nm	See note 11 below.
2. FORCE Model 2666 TX & RX	0 dBm (typ) @1.5 Gbps	-21 dBm (min) @1.5 Gbps	-7 dBm to -21 dBm MFB[7] =18 dB @ 1.5 Gbps	Flag bit for low light level.	10 Kbps	1.5 Gbps	1300 nm 1550 nm	2 nm (@1300 nm) 7 nm (@ 1550 nm)
3. FORCE Model 2753 TX & RX	-3 dBm (min) -2 dBm (typ) +0.5 dBm (max) @ 1310 nm[1] 622 Mbps	-28 dBm (min) @ 622 Mbps	-4 dBm to -28 dBm MFB[7] =25 dB @ 622 Mbps	Low light level, excessive light level indicators.	1 Mbps	622 Mbps	1310 nm 1550 nm[2]	2 nm (typ @ 1310nm) 5 nm (max @ 1310nm) 0.5 nm (max @ 1550 nm)
4. LDI Airpak TX & RX	-5 dBm (min) -3 dBm (typ) 0 dBm (max) @ 1310 nm[3] @ 52 Mbps	- 38 dBm (min) -40 dBm (typ) @ 52 Mbps[4]	0 dBm to -38 dBm @ 52 Mbps MFB[7] =33 dB @ 52 Mbps	RX photo-current. Back facet monitor on TX.	1 Mbps	155 Mbps	1310 nm 1550 nm[5]	2 nm (typ)
5. LDI Ruggedized TX & RX	-16 dBm (typ) @ 52 Mbps	-30 dBm (min) -32 dBm (typ) @52 Mbps	-16 dBm to -30 dBm MFB[7] =11 dB @52 Mbps	Flag bit for low light level on RX.	1 Mbps	125 Mbps	1270 nm to 1380 nm	180 nm (max)
6. Lucent 1241 & 1340 TX & RX	-5 dBm (min) -2 dBm (typ) 0 dBm (max) @155 Mbps	-36 dBm (min) -38 dBm (typ) @155 Mbps	-3 dBm to -36 dBm MFB[7] =33 dB @155 Mbps	RX photo-current. Back facet monitor on TX.	1 Mbps	155 Mbps	1310 nm 1550 nm	4 nm (max)

TX / RX Manufacturer	TX Output Power	RX Sensitivity	RX Dynamic Range	Power Monitoring	Min. Bit Rate Supported	Max. Bit Rate Supported	Wavelengths Available	Spectral Width
7. Nortel LCV75CD PTAV622	0 dBm (typ) @52 Mbps	-40 dBm (min) -43 dBm (typ) @52 Mbps	0 dBm to -40 dBm MFB[7]=37 dB @52 Mbps	RX photo-current. Back facet monitor on TX.	16 Mbps	155 Mbps	1310 nm[8]	2.5 nm (max)
8. OCP STX / SRX TX & RX[6]	- 3 dBm (min) 0 dBm (typ) +2 dBm (max) @52 Mbps	-40 dBm (min) -42 dBm (typ) @52 Mbps	-3 dBm to -40 dBm MFB[7]=37 dB @52 Mbps	RX photo-current. Back facet monitor on TX.	5 Mbps (for OC-1 TX/RX)	100 Mbps (for OC-1 TX/RX)	1310 nm 1550 nm	1 nm (max)
9. Agilent HFBR-1312T Transmitter HFBR-2316T Receiver	-17.5 dBm (min) -13.5 dBm (typ) -11.0 dBm (max)	-38.5 dBm (min)[12] -42 dBm (typ)[12]	-11 dBm to -38 5 dBm MFB[7] = 21 dB	RX photo-current	2 Mbps	125 Mbps	1300 nm	130 nm (typ) 185 nm (max)

1. At 1550 nm operation, the minimum transmitter power for the FORCE Model 2753 is -2.0 dBm, the typical transmitter power is 0 dBm, and the maximum transmitter power is +2.0 dBm.
2. At 1310 nm operation, the actual range of possible transmitter wavelengths for the FORCE Model 2753 is 1270 nm to 1330 nm. At 1550 nm operation, the actual range of possible transmitter wavelengths is 1520 nm to 1570 nm.
3. At 1550 nm operation, the minimum transmitter power for the LDI Airpak is -10.0 dBm, the typical transmitter power is -8.0 dBm, and the maximum transmitter power is -5 0 dBm.
4. At data rates of 155 Mbps, the receiver sensitivity of the LDI Airpak is less than -36 dBm, and is typically -38 dBm.
5. At 1310 nm operation, the actual range of possible transmitter wavelengths for the LDI Airpak is 1290 nm to 1330 nm. At 1550 nm operation, the actual range of possible transmitter wavelengths is 1520 nm to 1570 nm.
6. Unless otherwise indicated, parameters for the OCP transmitters and receivers are specified for the OC-12 variety, the STX-12 and SRX-12.
7. MFB = Minimum Flux Budget. It is based on the minimum transmitter power, and the minimum receiver sensitivity. Where typical transmitter power only is specified, the minimum power is assumed to be 3 dB lower.
8. Receiver is capable of functioning at wavelengths between 1200 nm and 1600 nm.
9. ITU-T Recommendation G.957 defines 'short-haul' as corresponding to distances of approximately 15 km, and long-haul as corresponding to distances of approximately 40 Km for 1310 nm operation and 80 Km for 1550 nm operation.
10. ITU-T recommendations listed in this table are for STM-1 type signals, nominally 155 Mbps
11. For short haul applications less than or equal to 2 Km, the maximum recommended RMS spectral width is 40 nm for a MLM (Multi-Longitudinal Mode) source or 80 nm for an LED source. For short haul applications of approximately 15 Km in length, the maximum recommended RMS spectral width is 7.7 nm for a 1310 nm source and 2.5 nm for a 1550 nm source. For long haul applications, the maximum recommended RMS spectral with is 4 nm for a 1310 nm source and 2.5 nm for a 1550 nm source.
12. Both the typical and minimum receiver sensitivities for the HFBR-2316T receiver are specified as being 3 dB higher than the typical and minimum equivalent optical noise input powers. See the HFBR-0300 Series data sheet for details.

Table 8 - More Optical Specifications

TX / RX Manufacturer	Output Power Stability	Optical Rise Time	Optical Fall Time	Jitter	Detector Damage Threshold	Extinction Ratio	Sensitivity to Back Reflection
1. FOAM/ADM-2 Requirement	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not sensitive
2. ITU-T Recommendations G.957 and G.958[4]	Not specified	< 0.2 U.I. < 4 ns @ 50 Mbps	< 0.2 U.I. < 4 ns @ 50 Mbps	< 0 01 U.I. rms	Not specified	Short haul[5] 8.2:1 (min) Long haul[5] 10:1 (min)	<-24 dB[6]
2 FORCE Model 2666 TX & RX	- 1.0 dB (min) to + 1.0 dB (max)	35 ps (typ) 75 ps (max)	122 ps (typ) 190 ps (max)	for 0 dB loss: 7 ps (typ) 20 ps (max) for 12 dB loss: 10 ps (typ) 22 ps (max)	+ 10.0 dBm	5:1 (min) 10:1 (typ)	B.R. must be < -35 dB
3. FORCE Model 2753 TX & RX	Data not available	Data not available (TX typically used for digital video.	Data not available (TX typically used for digital video.	Data not available (TX typically used for digital video applications)	Data not available	Data not available	< -25 dB
4. LDI Airpak TX & RX	Unknown[1]	Unknown[1]	Unknown[1]	Unknown[1]	Unknown[1]	10:1 (min) 16:1 (typ)	Not sensitive to B.R.[3]
5. LDI Ruggedized TX & RX	Unknown[1]	2.5 ns (max)	2.5 ns (max)	Unknown[1]	Unknown[1]	5:1 (min)	LED source, not sensitive to B.R.
6. Lucent 1241 & 1340 TX & RX	Not known	1.0 ns (max)	1.0 ns (max)	Compliant with SONET specs[2]	Not measured.	10:1 (min)	DFB laser, data not available
7. Nortel LCV75CD PTAV622	+/- 0.5 dB	TX: 0.5 ns RX: 50 ps typ.	TX: 0.5 ns RX: 230 ps typ.	Compliant with SONET specs[2]	Not measured	User selectable 30 dB max at 25 °C 20 dB max at 85 °C	Not sensitive (Fabry-Perot device)
8. OCP STX / SRX TX & RX	+/- 0.1 dB	2 ns (max)	2 ns (max)	Compliant with SONET specs[2]	+3.0 dBm	10:1 (min)	Not sensitive (uses angle-faceted fibre tip in TX)

TX / RX Manufacturer	Output Power Stability	Optical Rise Time	Optical Fall Time	Jitter	Detector Damage Threshold	Extinction Ratio	Sensitivity to Back Reflection
9. Agilent Technologies HFBR-1312T Transmitter HFBR-2316T Receiver	-0.03 dB / °C (temperature compensating circuitry might be required)	1.8 ns (typ) 4.0 ns (max)	2.2 ns (typ) 4.0 ns (max)	Compliant with SONET specs[2]	Not measured	Not tested	LED source, not sensitive to BR.

1. The specified parameter has not been tested, but can be tested by LDI for a fee.
2. The SONET specification requires that the RMS jitter be less than 0.01 unit intervals (UI), i e. less than 200 ps for 50 Mbps operation.
3. Tests were performed on the TL2065PT-010FC (1550 nm operation, 155 Mbps typical bit rate) at Focal Technologies Co. to determine the maximum allowable back-reflected light power. Back reflected light levels as high as -4 dB were tested without hindering the performance of the transmitter or the data link.
4. ITU-T Recommendations listed in this table are for STM-1 type signals, nominally 155 Mbps
5. ITU-T Recommendation G.957 defines 'short-haul' as corresponding to distances of approximately 15 km, and long-haul as corresponding to distances of approximately 40 Km for 1310 nm operation and 80 Km for 1550 nm operation
6. Sensitivity to back reflection parameter is listed in the ITU-T Recommendations for STM-16 (i.e. 2.5 Gbps) only.

Table 9 - Electrical Specifications

TX / RX Manufacturer	Voltage Requirements	Current Requirements	Power Requirements	Operational Sensitivity to Voltage Fluctuations	Data Formats Supported	Over-Voltage Protection	Data Duty Cycle Range
1. FOAM/ADM-2 Requirement	Not specified	Not specified	Not specified	Not specified	Diff. ECL	Not specified	Not specified
2. FORCE Model 2666 TX & RX	+5 V, -5.2 V, -2.1 V	TX: I_{EE} = 75 mA (max) I_{TT} = 28 mA (max) RX: I_{CC} = 9 mA (max) I_{EE} = 140 mA (max)	TX: 0.46 W RX: 0.79 W	4.8 V $< V_{CC} <$ 5.5 V, Can go up to 6.0 V without damage. -5.3 V $< V_{EE} <$ -4.2 V -2.2 V $< V_{TT} <$ -2.0 V	Diff. ECL Single-ended ECL	none	Ideally 50%
3. FORCE Model 2753 TX & RX	Single Voltage between 12 V and 15 V	200 mA (max)	3 W (max)	See note 1 below.	Single-ended ECL	none	Ideally 50%
4. LDI Airpak TX & RX	TX: -5.2 V RX: -5.2V +5.0 V	TX: 130 mA (max) RX: 150 mA (max on +5.0 V supply)[2]	TX: 680 mW RX: 750 mW [2]	4.8 V $< V_{CC} <$ 5.3 V -5.5 V $< V_{EE} <$ -4.75 V	Diff. ECL / PECL	none	Ideally 50%
5. LDI Ruggedized TX & RX	TX: -5.2 V RX: -5.2 V	TX: 200 mA (max) RX: 125 mA (max)	TX: 1.04 W RX: 650 mW	-5.7 V $< V_{EE} <$ -4.7 V	Diff. ECL/ PECL	none	Ideally 50%
6. Lucent 1241 & 1340 TX & RX	TX: -5.0 V RX: -5.0 V +5.0 V	TX: 130 mA (max) RX: 150 mA (max) on +5 V 50 mA (max) on - 5 V	TX: 650 mW RX: 1 W	4.75 V $< V_{CC} <$ 5.25 V -5.5 V $< V_{EE} <$ -4.75 V -5.25 V $< V_{PIN} <$ -4.75 V	TX: Diff. PECL or ECL RX: Diff. PECL only. Need to have a converter such as the 100314 to output in ECL format.	Devices have protection designed in for protection against ESD. Able to withstand static dis- charges up to 4000 V.	Up to 60 / 40

TX / RX Manufacturer	Voltage Requirements	Current Requirements	Power Requirements	Operational Sensitivity to Voltage Fluctuations	Data Formats Supported	Over-Voltage Protection	Data Duty Cycle Range
7. Nortel LCV75CD PTAV622	TX: -5.0 V RX: -5.0 V +5.0 V	TX: 95 mA (max) RX: not available	TX: 0.5 W RX: not available	$4.5 V < V_{CC} < 5.5 V$ $-15 V < V_{EE} < 0.5 V$	Diff. ECL / PECL	TR-NWT-000870. PTAV devices are class 2, with a HBM threshold of 500 V.	Ideally 50 %
8. OCP STX / SRX TX & RX	TX: -5.0 V RX: -5.0 V +5.0 V	TX: 130 mA RX: 120 mA on +5 V [2]	TX: 0.65 W RX: 0.6 W [2]	$4.75 V < V_{CC} < 5.5 V$ $-5.5 V < V_{EE} < -4.75 V$	Diff. ECL / PECL	None	Ideally 50 %
9. Agilent HFBR-1312T Transmitter HFBR-2316T Receiver	TX: -5.0 V RX: -5.0 V	TX: I_F = 100 mA (typ) RX: 25 mA (max)	TX: 0.5 W RX: 125 mW	TX: $1.1 V < V_F < 1.7 V$ RX: $-0.5 < (V_{CC} - V_{EE}) < 6.0V$	Diff. ECL / PECL	MIL-STD-883 Method 3015 1 KV ESD protection	Ideally 5 0%

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1. The supply voltage is DC ranging from +12 Volts to +15 Volts. Operation at higher voltage is possible , but the upper operating temperature of the part should be derated 5°C for every Volt over +15 Volts. The units will tolerate moderate amounts of ripple, but this should not exceed 0.5 Volts peak-to-peak. It is critical that the supply voltage NEVER drops below +12 Volts for any part of the waveform. Voltages below +12 Volts will cause the internal voltage regulators to lose regulation which will disrupt the operation of the unit and cause unpredictable results.

2. The measured quantity does not take into account the current requirements of the -5 V supply for ECL data signaling.

Table 10 - Other Specifications

TX / RX Manufacturer	Packaging Types	Fibre Types Supported	Fibre Interface Types & Connection Options	Mean Time Before Failure	Price	Miscellaneous
1. FOAM/ADM-2 Requirement	Must be able to fit within a 2" diameter can	Multimode, 62.5 / 125 µm	Not specified	Not specified	Not specified	
2. FORCE Model 2666 TX & RX	Both TX & RX are in shielded enclosures & have 8 pins. Dimensions (TX & RX): Height = 0.5" Width = 0.75" Length = 1.5"[1]	Singlemode and multi-mode.	FC, SC, ST Single-mode fibre pigtail on TX. Multimode 50 / 125 µm pigtail on RX.	TX: 850 khrs at 25 °C 681 khrs at 45 °C RX: 1138 khrs at 25 °C 1540 khrs at 45 °C	2666TA-SCC US$900 2666RA-SCC US$990 Quantities of 100 units	
3. FORCE Model 2753 TX & RX	Both TX and RX are in enclosed shielded modules with 4 power pins and a single BNC connector for data. Dimensions (TX & RX): Height = 1.12" Width = 2.95" Length=5.75"	Singlemode and multi-mode.	FC, SC bushing only, no pigtail.	Unknown	2753-SCFC US$1260 2753 RA-SFFC US$1050 Quantities of 100 units	
4. LDI Airpak TX & RX	Both TX & RX come in a 20-pin dual-inline footprint. Dimensions (TX & RX): Height = 0.31" Width = 0.58" Length = 1.20"[1]	Singlemode and multi-mode.	FC / PC Single-mode fibre pigtail on TX. Multi-mode 50 / 125 µm pigtail on RX.	Unknown		
5. LDI Ruggedized TX & RX	Both TX & RX come in a 16-pin hermetically sealed package. Dimensions (TX & RX): Height =0.38" Width = 0.58" Length = 1.32"[1]	Multimode 62.5 / 125 µm fibre	ST receptacles on both TX and RX.	Unknown		

TX / RX Manufacturer	Packaging Types	Fibre Types Supported	Fibre Interface Types & Connection Options	Mean Time Before Failure	Price	Miscellaneous
6. Lucent 1241 & 1340 TX & RX	Both TX & RX come in a 20-pin DIP. Dimensions (TX & RX): Height=0.35" Width=0.64" Length=1.34" [1]	Singlemode and multi-mode.	FC / PC, SC, or ST fibre pigtails. Single-mode fibre pigtail on TX. Multimode 62.5 / 125 μm pigtail on RX.	25 TX's and 25 RX's were aged at 85 °C under bias for 5000 hrs. No failures occurred.	1241FAFC TX: US$259 (12-14 weeks leadtime) 1340TBPC RX: US$285 (6-8 weeks leadtime) Quantities of 100 units	
7. Nortel LCV75CD PTAV622	Both TX & RX come in a 8 pin mini-DIL Dimensions (TX & RX): Height=0.35" Width=0.30" Length=0.52" [1]	Singlemode and multi-mode	TX: single-mode pigtail RX: 50 / 125 multi-mode pigtail. SC or FC/PC connectors available on both TX and RX	MTBF > 69 years at 60 °C.	TX: US$150 RX: US$214 TX does not include drive circuitry.[2] Quantities of 100 units	TX and RX pass fibre pull tests, 1 Kg, 3 x 10 sec
8. OCP STX / SRX TX & RX	Both TX & RX come in a 20 pin DIP Dimensions (TX & RX): Height=0.37" Width=0.64" Length=1.26" [1]	Singlemode and multi-mode.	FC, ST, or SC Single-mode pigtail on TX. Multi-mode 50 / 125 μm pigtail on RX.	TX: MTBF = 82 years RX: MTBF = 70 years (60 % confidence levels)	TX: US$450 (STX-01-PSC-A-L0-LR1 quant. 100) RX: US$215 (SRX-03-PSC-A-quant. 100)	
9. Agilent Technologies HFBR-1312T Transmitter HFBR-2316T Receiver	Both TX & RX come in 8-pin DIP with connector receptacles[3] Dimensions (TX & RX): Height=0.40" Width=0.495" Length=1.174"	Multimode 62.5 / 125 μm fibre.	TX and RX use either ST or SC connector receptacles.	TX: MTBF = 220 years RX: MTBF = 20 9 years (90% confidence levels @ 60 °C)	HFBR-1312T US$63.30 (small quantities) HFBR-2316T US$51.02 (small quantities)	Some additional components required. See HFBR-0300 series data sheet for example circuits.

1. The lengths of the packages do not include the fibre pigtail or bushing.
2. See the LCV75 series application note AN0020 for details on the external components required for the laser driver circuitry.
3 The length dimensions for the HFBR-1312T and the HFBR-2316T include the lengths of the fibre-optic receptacles.

4.0 SUMMARY

4.1 Component Summary Chart

Table 11 below provides a summary of the degree to which the various fibre optic devices complied with the critical specifications and other important system requirements.

4.2 Recommendations

The Lucent or OCP SONET modules are recommended for use in the FOAM fibre optic telemetry system. Since the Lucent and OCP modules are nearly pin compatible, a suitable PCB layout will support both modules. Either or both types should be included in the qualification testing. A recommended test plan is provided in a separate document, *Fibre Optic Transmitter/Receiver Test Plan.*

Table 11 - FOAM Transmitter and Receiver Specification Summary

Transmitter-Receiver Specification	FOAM	Force 2666	Force 2753	LDI Airpak	LDI Rug.	Lucent 1243 Tx 1340 Rx	Nortel LCV75TX PTVA622	OCP STX SRX	Agilent HFBR-0300
1. Operating Temp.	■ -25 to +40°C ● -40 to +85°C	X	X	●	●	●	●	●	●
2. Storage Temp.	■ -40 to +70°C	X	X	■	■	■	■	■	■
3. Ambient Pressure	● 200 bar	------------Not specified by any supplier------------							
4. Shock	■ MIL-S-901C				□	□	□	□	□
5. Vibration	■ MIL-STD-167-1					□	□	□	□
6. Solvent Sensitivity	● Bayol 35				○		○	○	○
7. Transportability	● air, rail, truck, barge, ship	------------Not specified by any supplier------------							
9. Humidity	● 85% RH		●			●	●	●	●
10. Output Power	● -5 dBm	●	●	●	X	●	●	●	X
12. Min. Bit Rate	■ 25 Mbps	■ 10 kbps	■ 1 Mbps	■ 1 Mbps	■ 1 Mbps	■ 1 Mbps	■ 16 Mbps	■ 5 Mbps	■ 2 Mbps
13. Max. Bit Rate	■ 50 Mbps	■ 1.5 Gbps	■ 622 Mbps	■ 155 Mbps	■ 125 Mbps	■ 155 Mbps	■ 155 Mbps	■ 100 Mbps	■ 125 Mbps
21. Tx Power Monitor	● Analogue Out	X	X	●	X	●	●	●	X
21. Rx Power Monitor	■ Analogue Out	□ Flag	□ Flag	■	□ Flag	■	■	■	■
22. Min. Sensitivity	● -30 dBm	X	○	●	●	●	●	●	●
29. Tx Data Format	■ Diff. ECL	■	□ ECL	■	■	■	■	■	■
29. Rx Data Format	■ Diff. ECL	■	□ ECL	■	■	□ Dif. PECL	■	■	■
33. Rx Fibre Type	■ 62.5/125	□ 50/125	■	□ 50/125	■	■	□ 50/125	□ 50/125	■

FOAM :
■ = critical specification
● = non-critical specification

TX/RX :
■ = critical specification met or exceeded
● = non-critical specification met or exceeded
□ = critical specification may be acceptable (e.g. environmental standards used differ from FOAM spec.)
○ = non-critical specification may be acceptable (e.g. min. sensitivity of Force 2753 Rx is -29 dBm @ 622 Mbps)
X = specification is not met
Blank = specification is not given by supplier

APPENDICES

FIBRE OPTIC TELEMETRY SYSTEM DESIGN GUIDELINES

The primary considerations for design of a fibre optic telemetry system are optical flux budget, bandwidth (data rate), and return loss.

1. Optical Flux Budget

System design consists largely of preparing a flux budget as provided in the example in Table A-1. System losses in decibels (dB) are summed and subtracted from the optical budget as calculated from the difference between the transmitter launch power and the receiver sensitivity. Some margin should be allocated for temperature and aging effects, typically 6 dB. For high data rates over long cables, an additional 1-2 dB should be allowed as a dispersion penalty.

Worst case values for transmitter power (minimum), receiver sensitivity (maximum), and intervening sources of loss (connectors, fibre, etc.) are often used as a simple way to calculate flux budget. There are, however, more complex techniques employing mean values and variances of all components, as detailed in the Lucent (AT&T) application note, *Power Margin Analysis*, included in appendix A.2.

2. Bandwidth (Data Rate)

All transmitters and receivers must be rated to operate at the specified data rate. The length of the optical fibre limits the maximum data rate that can be effectively transmitted through the fibre due primarily to dispersion of the optical pulses, i.e. spreading of the digital pulses as they travel through the fibre.

Chromatic dispersion is caused by the difference in propagation speed of different photon wavelengths, a property of the fibre glass. Since all sources, even lasers, emit photons with a range of wavelengths, not one exact wavelength, the photons tend to spread out as they pass through the fibre. Chromatic dispersion is typically only a limiting factor in singlemode fibre systems.

Modal dispersion is typically the limiting factor in multimode fibres. Here the difference in propagation speed of photons corresponds to different power modes in the fibre. (Singlemode fibre, by definition, does not suffer from modal dispersion.) In essence, photons which propagate nearly straight down the center of the fibre (low order modes) arrive sooner than photons that follow an "angled" path (high order modes). Graded index fibres are normally used to maximize the bandwidth of multimode fibres by minimizing the effective time-of-flight differences between low and high order modes.

The bandwidth of optical fibre is specified as a bandwidth-distance product, typically 400-800 MHz-km for 50/125 µm and 62.5/126 µm fibres. A bandwidth-distance product of 500 MHz-km, for example, implies that the fibre has a bandwidth of 500 MHz over 1 km, 250 MHz over 2 km, etc., although the linearity of this relationship is only approximate and relies on assumptions of modal launch conditions. Use of lasers as sources with multimode fibre typically improves bandwidth, since fewer modes are normally excited, reducing modal dispersion. Imperfections near the core of the multimode graded index profile may, however, actually reduce effective bandwidth for lasers. (Results will vary from fibre spool to spool.) In any case, at the 25-50 Mbps

FOAM data rates over cable lengths less than 2 km, dispersion is not a limiting factor. In general, a given fibre bandwidth will support an NRZ bit rate 20-40% greater, e.g., a 100 MHz bandwidth can support 120-140 Mbps. Note that this corresponds to the optical baud rate on the fibre, which may be higher than the electrical input bit rate if 4B/5B encoding is used. More detailed explanations of fibre bandwidth-data products are given in the application notes.

3. Optical Return Loss (ORL)

Optical power reflected back to the laser transmitter — this does not affect LEDs — may cause instabilities in the laser output power, degrading signal-to-noise ratio at the receiver. The optical return loss is the power difference in dB between the outgoing transmitter power and the returning optical power, which is the integration of all back reflections from fibre optic connectors, FORJs, the receiver detector, and scattering in the fibre itself.

Typical laser sources specify that ORL should exceed 25 dB in a singlemode system. But lasers with low power outputs (< 0 dBm) usually have poor coupling between the fibre pigtail and laser, and hence tend to be less sensitive to back reflection. Moreover, the use of singlemode pigtailed lasers with multimode fibre causes a large attenuation of back reflections due to the core mismatch of the fibres. Subsequently, the recommended transmitters and receivers for the FOAM telemetry system should not be very sensitive to high levels of back reflection.

Nevertheless, it is good practice to minimize back reflections in the fibre optic cable system to maintain a large margin in the event that a large back reflection occurs during a fault condition, for example a damaged connector. Low back reflection connectors should be used throughout the system. Highly recommended are ST or FC connectors having standard PC (physical contact) finishes with return losses exceeding 40 dB. Optical index matching materials may be used to reduce reflections at mated connectors. The sensitivity of the selected transmitter to back reflections should be verified as part of the test plan.

Reflected power at the interface between materials with different indices of refraction may be calculated based on Fresnel's equations:

$$\mathrm{Pr} = \mathrm{Pi}\,[(n_1 - n_2)/(n_1 + n_2)]^2\,,$$

where Pi is the incident power in mW, Pr is the reflected power in mW, n_1 is the index of refraction of the material on the incident side of the interface, and n_2 is the index of refraction of the transmitted side of the interface. ORL is given by the formula

$$\mathrm{ORL\ (dB)} = -\log_{10}(\mathrm{Pr} / \mathrm{Pi})$$

An glass-air interface reflects roughly 4% of the incident power, with $n_1=1.5$ and $n_2=1$. This causes an insertion loss of only 0.2 dB, but induces a back reflection of -14 dB, i.e. ORL is only 14 dB. This example highlights the fact that even "good" connections in terms of insertion loss may have excessive reflected power.

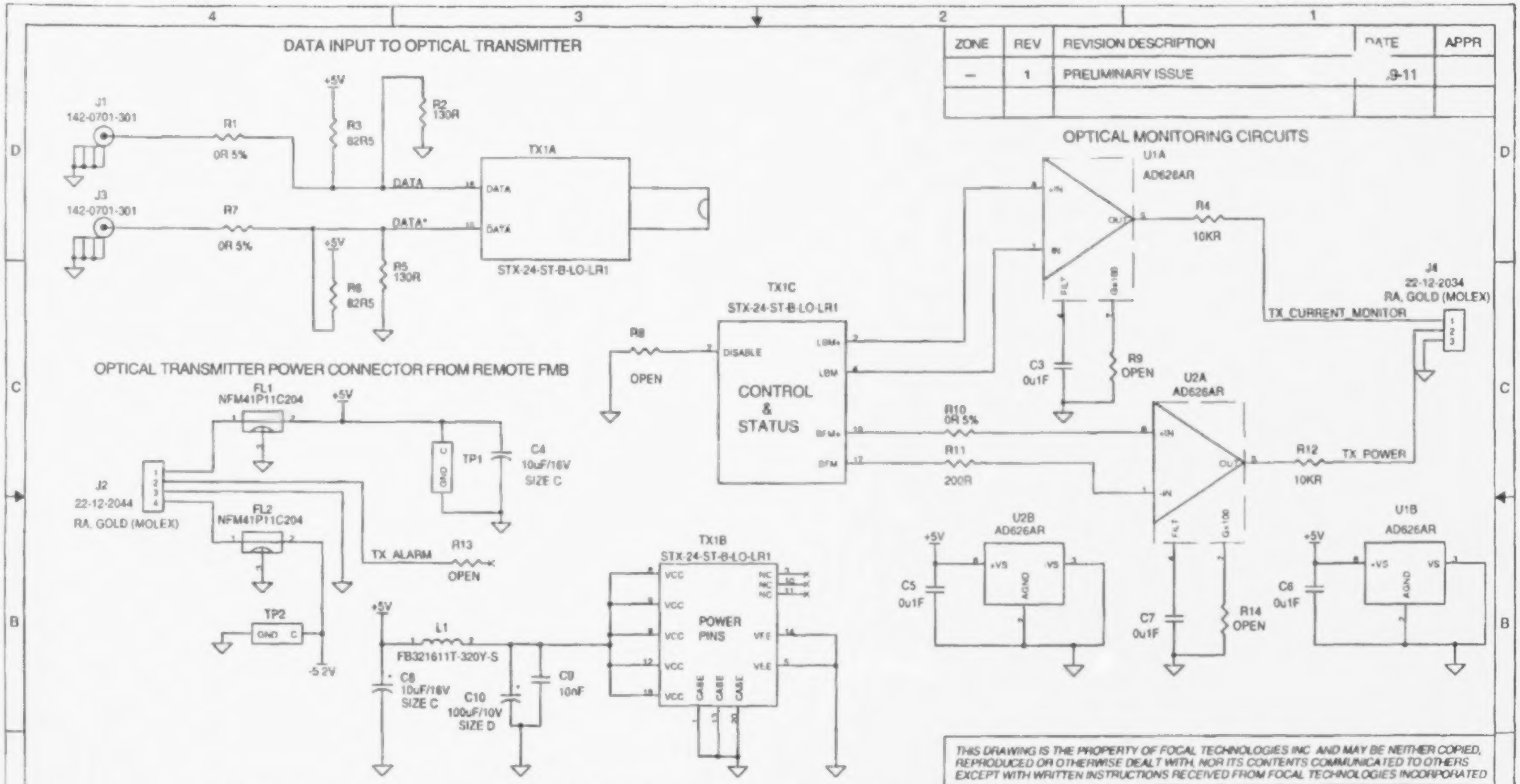
Table A-1 - Typical Flux Budget Analysis

Fibre Loss (62.5/125 μm)	1.0 dB/km @ 1310 nm
Connector is ST-PC	0.5 dB/conn
FORJ Loss	4.0 dB

LINK	**UPLINK DATA**
Rate	25 - 50 Mbps
Direction	Array to Surface
Wavelength	1310 nm

Minimum Output Power at the Transmitter	**-5.0**
Connector	-0.5
Connector	-0.5
Connector	-0.5
Connector	-0.5
Cable (for 2 km length)	-2.0
Connector	-0.5
Connector	-0.5
Winch FORJ	-4.0
Connector	-0.5
Connector	-0.5
Losses	-10.0
Margin	-6.0
Dispersion Penalty	-2.0
Required Sensitivity at Receiver	**-23.0**
Maximum Specified Sensitivity at Receiver	-30.0

ZONE	REV	REVISION DESCRIPTION	DATE	APPR
–	1	PRELIMINARY ISSUE	.9-11	


DATA INPUT TO OPTICAL TRANSMITTER
J1
142-0701-301
J3
142-0701-301
R1
0R 5%
R7
0R 5%
+5V
R3
82R5
R2
130R
R5
130R
R6
82R5
DATA
DATA*
TX1A
STX-24-ST-B-LO-LR1
OPTICAL TRANSMITTER POWER CONNECTOR FROM REMOTE FMB
FL1
NFM41P11C204
FL2
NFM41P11C204
J2
22-12-2044
RA, GOLD (MOLEX)
TP1
C4
10uF/16V
SIZE C
TX_ALARM
R13
OPEN
TP2
-5.2V
L1
FB321611T-320Y-S
C8
10uF/16V
SIZE C
C10
100uF/10V
SIZE D
C9
10nF
TX1B
STX-24-ST-B-LO-LR1
POWER
PINS
VCC
CASE
NC
VEE
R8
OPEN
TX1C
STX-24-ST-B-LO-LR1
DISABLE
CONTROL
&
STATUS
LBM+
LBM
BFM+
BFM
OPTICAL MONITORING CIRCUITS
U1A
AD626AR
R4
10KR
C3
0u1F
R9
OPEN
TX_CURRENT_MONITOR
J4
22-12-2034
RA, GOLD (MOLEX)
R10
0R 5%
R11
200R
U2A
AD626AR
R12
10KR
TX_POWER
C7
0u1F
R14
OPEN
U2B
AD626AR
C5
0u1F
U1B
AD626AR
C6
0u1F
+VS
VS
AGND

NOTE:
1. CAPACITORS C1 AND C2 ARE NOT ON THIS DESIGN (REQUIRED FOR 2.5Gbps DESIGN)
2. LAST USED REFERENCE DESIGNATORS
C10, J4, FL2, L2, R14, TX1, TP2, U2
3. ALL RESISTORS ARE 1% SMT 0805 UNLESS OTHERWISE STATED.
4. TEST POINTS TP1 AND TP2 ARE FOR SCOPE PROBES.
5 STX-24 TYPICAL USE: DIFFERENTIAL SIGNAL
ON FMB-REMOTE BOARD: REMOVE R8, R9
6 STX-24 IS A CLASS I LASER PRODUCT

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DRAWN CS BOWERS
CHECKED
APPROVED
DATE 1999-11-19
FILENAME STX-24_R1.DSN
SHEET 1 OF 1

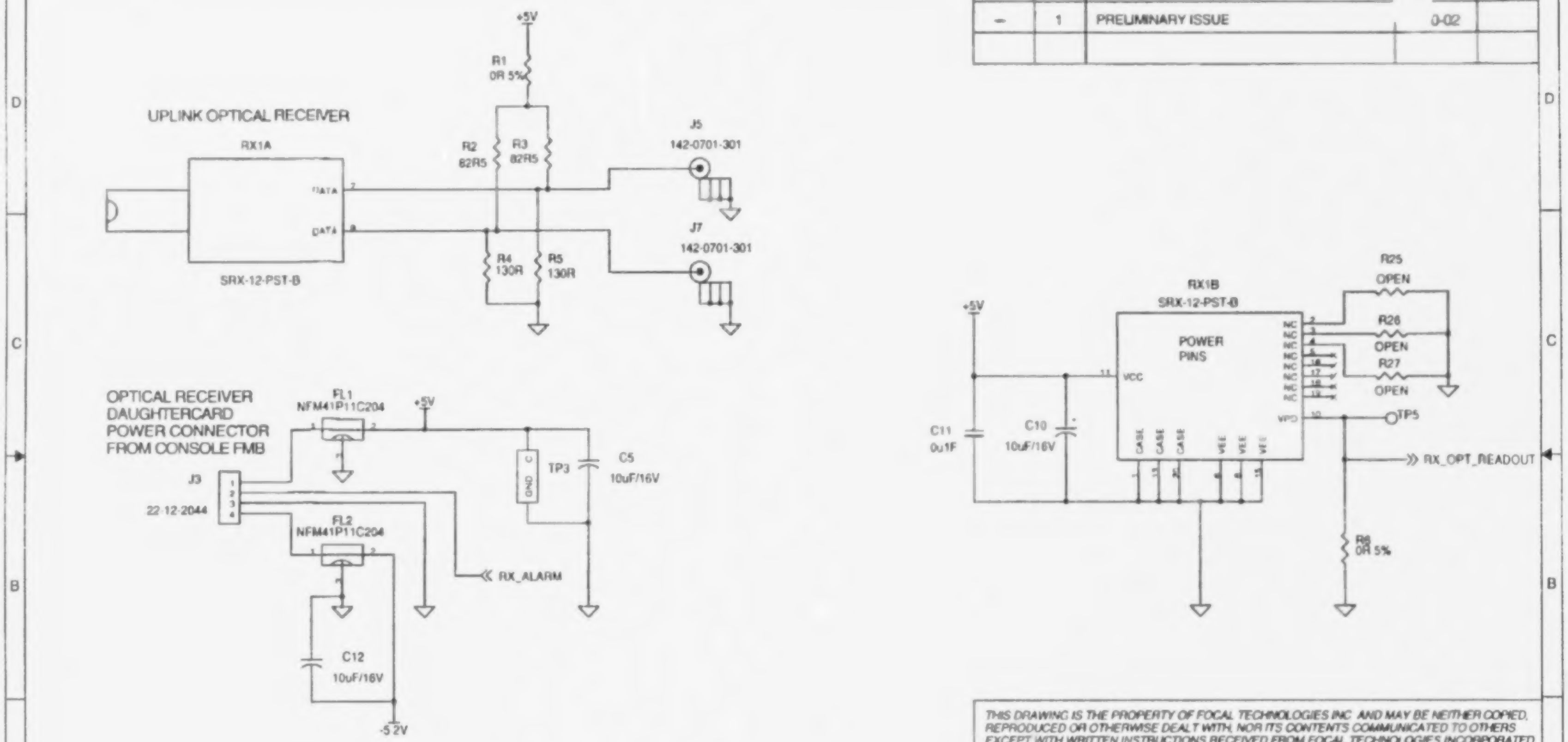
FOCAL TECHNOLOGIES INC.
40 THORNHILL DR., UNIT 7
DARTMOUTH, NS, CANADA, B3B 1S1

TITLE HIGH SPEED OPTICAL TRANSMITTER BOARD

SIZE	TYPE	DRAWING NO	ISSUE
B	SK	903-0537-00	1

UNCONTROLLED
0 2000
PRINT

ZONE	REV	REVISION DESCRIPTION	DATE	APPR
–	1	PRELIMINARY ISSUE	0-02	


4
3
2
1
D
C
B
A
UPLINK OPTICAL RECEIVER
RX1A
DATA
DATA*
SRX-12-PST-B
+5V
R1
0R 5%
R2
82R5
R3
82R5
R4
130R
R5
130R
J5
142-0701-301
J7
142-0701-301
OPTICAL RECEIVER
DAUGHTERCARD
POWER CONNECTOR
FROM CONSOLE FMB
J3
22-12-2044
FL1
NFM41P11C204
FL2
NFM41P11C204
+5V
TP3
GND
C5
10uF/16V
RX_ALARM
C12
10uF/16V
-5.2V
RX1B
SRX-12-PST-B
POWER
PINS
VCC
NC
VPD
CASE
VEE
+5V
C11
0u1F
C10
10uF/16V
R25
OPEN
R26
OPEN
R27
OPEN
TP5
RX_OPT_READOUT
R6
0R 5%

NOTE:

1. CAPACITORS FOR DATA/DATA* ARE LOCATED ON THE FMB CARD.
2. LAST USED REFERENCE DESIGNATORS:
   C17, J7, FL2, R27, RX1, TP5, U3
   CONNECTOR DESIGNATORS NOT USED: J1, J2, J4, J6
3. ALL RESISTORS ARE 1% SMT 0805s UNLESS OTHERWISE STATED.
4. R25-R27 SHOULD BE 0R 5% WHEN USING AN LDI OC-12 AIRPAK RECEIVER.

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DRAWN: CS BOWERS
CHECKED:
APPROVED:
DATE: 2000-02-23
FILENAME: OC-12_RXR1.DSN
SHEET: 1 OF 2

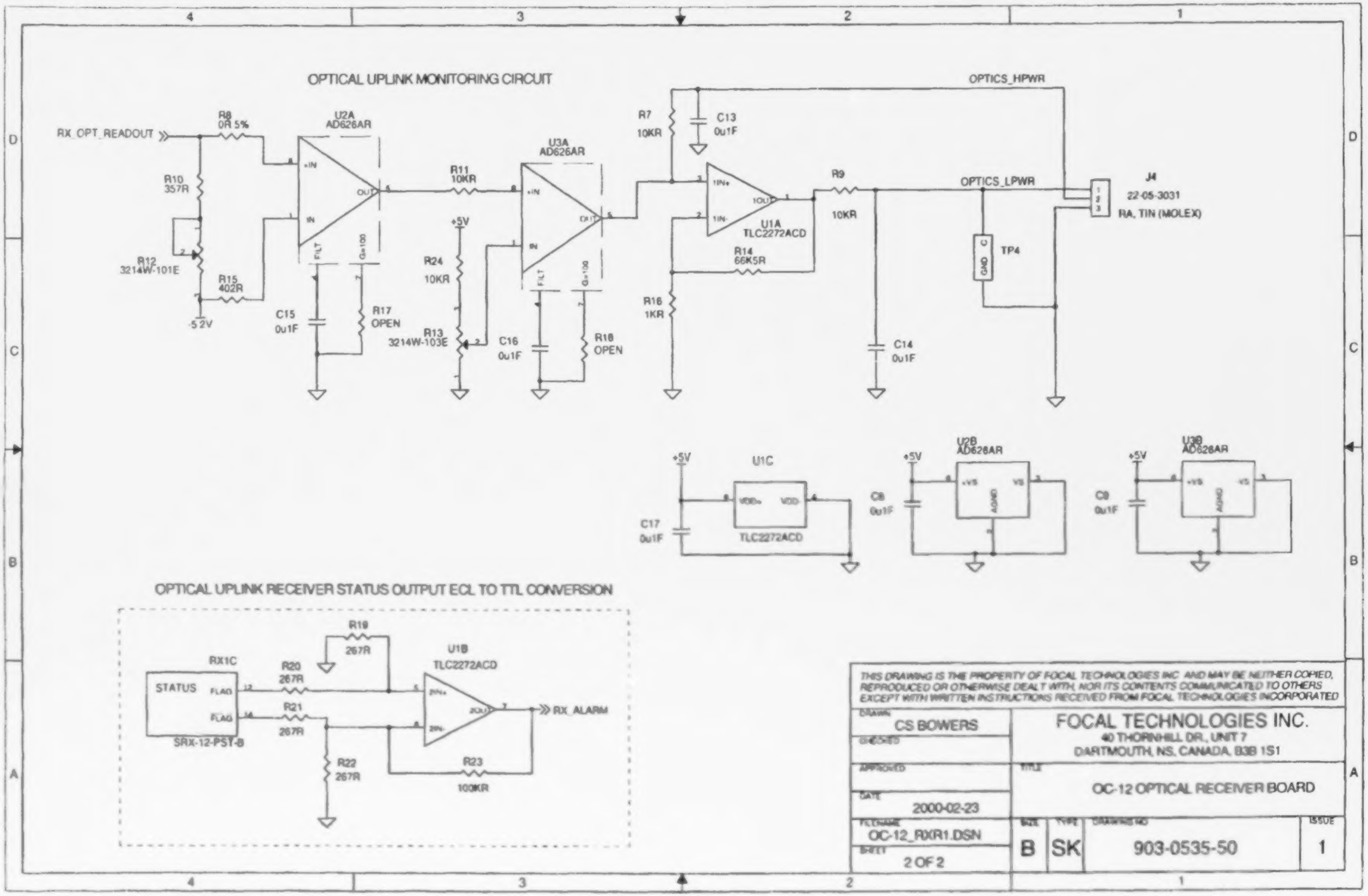
FOCAL TECHNOLOGIES INC.
40 THORNHILL DR., UNIT 7
DARTMOUTH, NS, CANADA, B3B 1S1

TITLE: OC-12 OPTICAL RECEIVER BOARD

SIZE	TYPE	DRAWING NO	ISSUE
B	SK	903-0535-50	1

UNCONTRO

PRINT


OPTICAL UPLINK MONITORING CIRCUIT
RX_OPT_READOUT
R8
0R 5%
R10
357R
R12
3214W-101E
R15
402R
-5.2V
U2A
AD626AR
+IN
IN
OUT
FILT
G=100
C15
0u1F
R17
OPEN
R11
10KR
+5V
R24
10KR
R13
3214W-103E
U3A
AD626AR
C16
0u1F
R18
OPEN
R7
10KR
C13
0u1F
R16
1KR
U1A
TLC2272ACD
1IN+
1IN-
1OUT
R14
66K5R
R9
10KR
C14
0u1F
OPTICS_HPWR
OPTICS_LPWR
TP4
GND
C
J4
22-05-3031
RA, TIN (MOLEX)
U1C
VDD+
VDD-
TLC2272ACD
C17
0u1F
U2B
AD626AR
+VS
-VS
AGND
C8
0u1F
U3B
AD626AR
C9
0u1F
OPTICAL UPLINK RECEIVER STATUS OUTPUT ECL TO TTL CONVERSION
RX1C
STATUS
FLAG
SRX-12-PST-B
R20
267R
R21
267R
R19
267R
R22
267R
U1B
TLC2272ACD
2IN+
2IN-
2OUT
R23
100KR
RX_ALARM
1
2
3
4
A
B
C
D

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CHECKED:
APPROVED:
DATE: 2000-02-23
FILENAME: OC-12_RXR1.DSN
SHEET: 2 OF 2

FOCAL TECHNOLOGIES INC.
40 THORNHILL DR., UNIT 7
DARTMOUTH, NS, CANADA, B3B 1S1

TITLE: OC-12 OPTICAL RECEIVER BOARD

SIZE: B
TYPE: SK
DRAWING NO: 903-0535-50
ISSUE: 1

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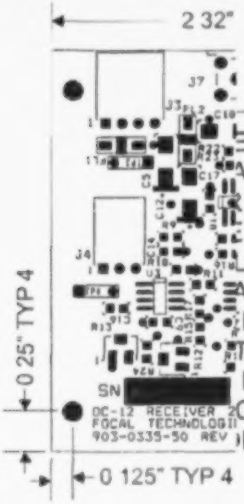
:SCRIPTION	DATE	APPR.
Y ISSUE	2000-02	

TOP SIDE VIEW S 08:38)TO PCB MANUFACTURER
VIAS, AND SILKS(



	FORMAT
EN LAYER	EXTENDED GERBER
ASK LAYER	EXTENDED GERBER
(	EXTENDED GERBER
: LAYER	EXTENDED GERBER
LAYER	EXTENDED GERBER
AYER	EXTENDED GERBER
:R MASK	EXTENDED GERBER
TION	EXCELLON NRZ FORMAT
INFORMATION	EXTENDED GERBER
ORMATION	ASCII TEXT
ETAILS FILE	ASCII TEXT

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PRINT

NOTES: 4 LAYER PCB WITH 1

TOP FOIL LAYER
GROUND PLANE LAY
POWER PLANE LAYE
BOTTOM FOIL LAYEF

SILKSCREEN IS TOP
PCB COLOUR IS GRI
THICKNESS IS 0.062"
SOLDERMASK ON B(

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)CAL TECHNOLOGIES INCORPORATED.

FOCAL TECHNOLOGIES INC.
40 THORNHILL DRIVE, UNIT 7
DARTMOUTH, NS CANADA, B3B 1S1

OC-12 RECEIVER PCB

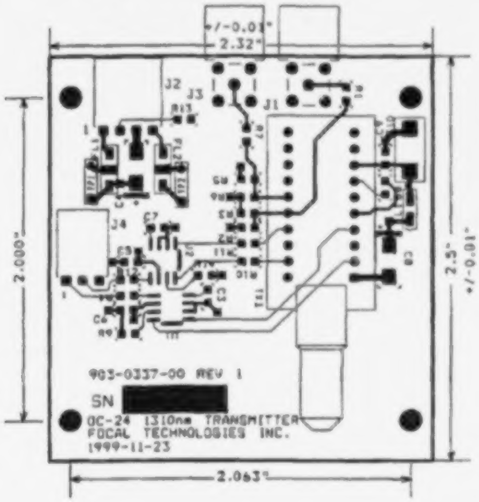
YPE	DRAWING NO.	ISSUE
SK	903-0335-50	1

4 1

SCRIPTION	DATE	APPR.
RY ISSUE	1999-11	

D D

TOP SIDE VIEW SHOWIN COMPONENTS, VIAS, SIL AND DRILL CHART


+/-0.01"
2.32"
J2
J3
J1
R13
J4
C7
C3
C6
R9
R10
R3
U1
2.000"
2.5"
+/-0.01"
2.063"
903-0337-00 REV 1
SN [redacted]
OC-24 1310nm TRANSMITTER
FOCAL TECHNOLOGIES INC.
1999-11-23

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PRINT

C C

O PCB MANUFACTURER VIA E-MAIL

DRILL CHART				
SYM	DIAM	TOL	QTY	N
×	0.028	+/-0.04	13	FINISHE
+	0.034	+/-0.03	24	FINISHE
▩	0.042	+/-0.04	7	FINISHE
■	0.060	+/-0.04	10	FINISHE
◇	0.110	+/-0.04	4	FINISHE
TOTAL			58	

	FORMAT
LAYER	EXTENDED GERBER
LAYER	EXTENDED GERBER
	EXTENDED GERBER
	EXTENDED GERBER
	EXTENDED GERBER
MASK	EXTENDED GERBER
N	EXCELLON NRZ FORMAT
ORMATION	EXTENDED GERBER
MATION	ASCII TEXT
AILS FILE	ASCII TEXT

B B

F FOCAL TECHNOLOGIES INC. AND MAY BE
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CAL TECHNOLOGIES INCORPORATED.

NOTE:

1. FOUR LAYER PC
2. - PCB COLOUR:(
   - SILKSCREEN:T
   - SILKSCREEN C
   - BOARD THICK
3. MATERIAL = FR
4. PLANE LAYERS
   (NO COPPER IS
   THESE LAYERS

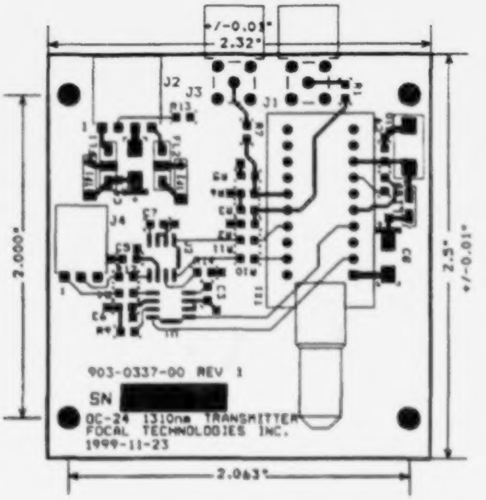
FOCAL TECHNOLOGIES INC.
40 THORNHILL DRIVE, UNIT 7
DARTMOUTH, NS CANADA, B3B 1S1

A A

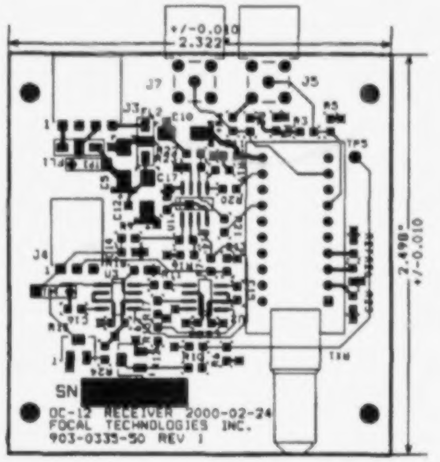
24 1310nm TRANSMITTER PCB

PE	DRAWING NO.	ISSUE
K	903-0337-00	1

4 1


+/-0.01"
2.32"
J2
J3
J1
J4
2.000"
2.5"
+/-0.01"
903-0337-00 REV 1
SN [redacted]
OC-24 1310nm TRANSMITTER
FOCAL TECHNOLOGIES INC.
1999-11-23
2.063"

DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
×	0.028	+/-0.04	13	FINISHED SIZE
+	0.034	+/-0.03	24	FINISHED SIZE
■	0.042	+/-0.04	7	FINISHED SIZE
▣	0.060	+/-0.04	10	FINISHED SIZE
◇	0.110	+/-0.04	4	FINISHED SIZE
TOTAL			58	

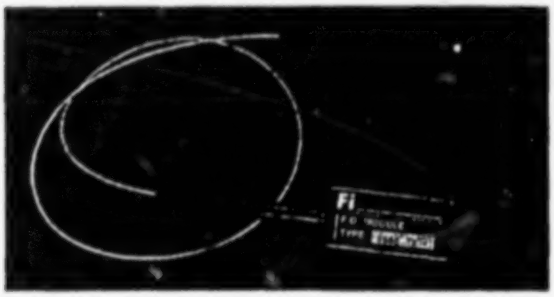

+/-0.010
2.322"
J7
J5
J3
J4
TP5
2.498"
+/-0.010
SN [redacted]
OC-12 RECEIVER 2000-02-24
FOCAL TECHNOLOGIES INC.
903-0335-50 REV 1

DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
×	0.028	+/-0.03	30	FINISHED SIZE
+	0.034	+/-0.03	21	FINISHED SIZE
◇	0.037	+/-0.03	4	FINISHED SIZE
■	0.042	+/-0.04	7	FINISHED SIZE
▣	0.060	+/-0.04	10	FINISHED SIZE
×	0.110	+/-0.04	4	FINISHED SIZE
TOTAL			76	

TECHNICAL BULLETIN

TB
100K
MODEL
2666

HIGH-SPEED FIBER OPTIC MODULES



1978 – 1998
Fi Force, Incorporated
20
Light Years
... and Beyond

The Force, Incorporated Model 2666 High-speed Fiber Optic Modules provide a high quality system for transferring high-speed asynchronous NRZ digital data with complete EMI immunity via fiber optics at speeds from 50 Mb/s to 1.5 Gb/s. The Fiber Optic Modules offer excellent performance with up to 12 dB optical loss. The transmitter uses a 1300 nm or 1550 nm laser diode, and the receiver uses a PIN diode detector for maximum reliability and performance. Each unit is built in a rugged enclosure that offers excellent EMI/RFI shielding. Power is from +5 Volts, -5.2 Volts and -2 Volts DC nominal. Used with a good quality single-mode optical fiber, the modules will meet all specifications over at least 10 km of fiber. Much longer distances, 30-40 km, are readily achievable if care is taken to use low-loss splices or connectors. The modules are designed to solder directly to a printed circuit board. The transmitter and receiver interface with 10k or 100k ECL levels and feature single-ended or differential interfaces. The receiver features a loss-of-signal flag output that indicates when the incoming light level is too low for reliable operation. State-of-the-art electro-optics and high reliability silicon circuitry make the Model 2666 the industry leader in performance and price. Optional models exist for NRZ data transmission and serial digital video transmission.

Digitized Video Model Now Available!

Optimized to Handle Pathological Code Test!

FEATURES

- 10k or 100k ECL Compatible Inputs/Outputs
- Differential or Single-Ended Inputs/Outputs
- NRZ Asynchronous Data, 50 Mb/s to 1.5 Gb/s
- Low Bit Error Rate (BER) < 10^{-12}
- 12 -20 dB Optical Loss Range Using 1300 nm or 1550 nm Optics
- Rugged, Shielded Enclosure
- No User Adjustments or Setup Required
- Min. Operating Range 10 km, Typ. > 20 km
- SM Fiber Pigtail Interface on Transmitter
- MM Fiber Pigtail Interface on Receiver
- Loss-of-Signal Flag on Receiver
- Chatter-Free Receiver Output
- Asymmetrical Mounting Pattern Prevents Improper Installation
- Complete Link MTBF > 454,000 Hours
- Optional Model for Full Compliance for Digitized Video Applications (i.e. Passes Pathological Code Test)

APPLICATIONS

- SONET OC-1 to OC-24
- Fibre Channel
- HIPPI
- High-speed Computer Interconnects
- Hot Rod™ Applications
- Digitized Video Data Streams
- NTSC Video
- PAL Video
- Digitized HDTV Applications

Fi Force, Incorporated
Fiber Optics and Electronics

825 Park Street (PO Box 2045)
Christiansburg, VA 24073
(800) 732-5252 • (540) 382-0462
Fax: (540) 381-0392

E-Mail: force@forceinc.com
Web Page: www.forceinc.com

OPTICAL AND ELECTRICAL CHARACTERISTICS: @ 25 °C, SM FIBER, 1300 NM OR 1550 NM

	Min.	Typ.	Max.	Units	Notes
NRZ Data Rate (options A and B)	50		1500	Mb/s	
NRZ Data Rate (options C and D)	0.01		1500	Mb/s	
Bit Error Rate (BER)			10^{-12}	BER	1
SUPPLY VOLTAGES					
V_{cc} Supply Voltage	4.80	5.00	5.50	V_{DC}	2
V_{EE} Supply Voltage	-5.30	-5.20	-4.20	V_{DC}	
V_{TT} Supply Voltage	-2.20	-2.10	-2.00	V_{DC}	
TRANSMITTER					
I_{EE} Supply Current		69	75	mA	
I_{TT} Supply Current		25	28	mA	
RECEIVER					
I_{CC} Supply Current		8	9	mA	
I_{EE} Supply Current		116	140	mA	
LINK					
Electrical Rise Time (Receiver Output)		175	220	ps	3
Electrical Fall Time (Receiver Output)		175	225	ps	3
Allowable Optical Loss	0		12	dB	
Operating Wavelength (1300 nm Model)	1270	1300	1330	nm	4
Operating Wavelength (1550 nm Model)	1520	1550	1570	nm	4
Spectral Width (FWHM) (1300 nm Model)		2	5	nm	5
Spectral Width (FWHM) (1550 nm Model)		7	10	nm	5
Optical Output Power (Tx)	-9.0	-8.0	-7.0	dBm	6
Output Power Stability	-1.0		+1.0	dB	
Optical Rise Time		35	75	ps	7
Optical Fall Time		122	190	ps	7
Duty Cycle Performance	45	49	53	%	8
Random Jitter, Rising Edge (0 dB Loss)		7	20	ps	9
Random Jitter, Falling Edge (0 dB Loss)		5	15	ps	9
Random Jitter, Rising Edge (12 dB Loss)		10	22	ps	9
Random Jitter, Falling Edge (12 dB Loss)		9	20	ps	9
Optical Input Power (Rx)			-7.0	dBm	
Optical Sensitivity (Rx)	-21.0			dBm	2, 10
Receiver Cutoff Hysteresis		0.5		dB	11
Detector Damage Threshold	+10			dBm	12
Extinction Ratio (Tx)	5:1	10:1		@100 MHz	
Laser Reflection			-25	dB	13
Required Fiber Bandwidth	1250			MHz	
Reference Voltage V_{bb} (Tx)	-1380	-1310	-1240	mV	
Data Type	NRZ				
Data Input	Single-Ended/Differential				14
Data Output	Single-Ended/Differential				15
LOSS-OF-SIGNAL FLAG					
Open Circuit Voltage	0	+5	+12	V_{DC}	16, 10
Sink Current	0		60	mA	16, 10
DC ELECTRICAL CHARACTERISTICS (FOR HIGH-SPEED DATA I/O PINS)					
Output HIGH Voltage	-1020	-880	-780	mV	
Output LOW Voltage	-1880	-1700	-1605	mV	
Input HIGH Voltage	-1165		-810	mV	
Input LOW Voltage	-2000		-1525	mV	
Input/Output Impedance (options A & B)		50		Ohms	17
Input/Output Impedance (options C & D)		75		Ohms	17

PHYSICAL AND ENVIRONMENTAL CHARACTERISTICS

	Min.	Typ.	Max.	Units	Notes
Weight (Either Tx or Rx)		3 85.05		oz. g	
Dimensions	1.50 x 0.75 x 0.50 38.1 x 19.1 x 12.7			in. mm	
Operating Temperature Range	-10		+55	℃	
Storage Temperature Range	-20		+70	℃	
Case Operating Temperature	+5		+50	℃	
THERMAL RESISTANCE (PACKAGE TO AIR) - SEE FIGURE 1					
Still Air		21		℃/W	18
100 Linear Feet/Minute		15		℃/W	18
200 Linear Feet/Minute		10		℃/W	18
300 Linear Feet/Minute		7		℃/W	18
MEAN TIME BETWEEN FAILURE (MTBF) @ 25 ℃					
2666R Receiver		1540		kHrs	19
2666T Transmitter		850		kHrs	19
2666 Complete Link		547		kHrs	19
MEAN TIME BETWEEN FAILURE (MTBF) @ 45 ℃					
2666R Receiver		1138		kHrs	19
2666T Transmitter		681		kHrs	19
2666 Complete Link		426		kHrs	19

SPECIFICATION NOTES

1) The specified BER is guaranteed for. 0 dB £ Optical Loss £ 12 dB, 50 Mb/s Data Rate £ 1500 Mb/s, -10 ℃ £ Ambient Temperature £ +55 ℃.

2) The receiver will operate at V_{CC} voltages to +6.0 Volts with no damage. However, the cutoff threshold may drift

3) Applies to receiver "DATA OUT" signals Load = 50 Ohms (75 Ohms) to -2.0 Volts. Load capacitance C_L £ 2 pF. Rise and fall times are 20-80% values. The rise time degrades by approximately 50 picoseconds per picofarad of additional load capacitance (over 2 picofarads) and the fall time degrades by approximately 100 picoseconds per picofarad of additional load capacitance (over 2 picofarads).

4) The wavelength range given is the range of the center wavelength of the laser diode in the transmitter. The receiver meets all specifications with wavelengths from 1200 nm to 1575 nm.

5) The spectral width given is the Full Width Half Maximum (FWHM) of the transmitter optical output.

6) Average optical output power, square wave data pattern.

7) Optical rise and fall time is 20-80% measured using a Hewlett-Packard 83411A Optical Receiver with H27 option.

8) The duty cycle parameter is measured using a '1010' data pattern at a data rate of 1.26 Gb/s. This amounts to a square wave input at a frequency of 630 MHz. The measurement is performed using a Hewlett-Packard 54121T, 20 GHz digitizing oscilloscope. The specification is for 0 dB optical loss.

9) Random jitter is an Root Mean Square (RMS) value. Jitter is measured using a Hewlett-Packard 54121T, 20 GHz digitizing oscilloscope. Examples of the random jitter measurement can be seen in Figures 12 and 13.

10) When the LOS flag on the receiver is high, indicating that insufficient light is present to guarantee proper operation, the receiver data output is strobed off.

11) A slight amount of hysteresis is introduced in the receiver Loss-of-Signal circuit to reduce chatter near the cutoff threshold

12) The detector used in the receiver can tolerate optical input levels of +10 dBm without damage. The receiver will operate properly only at levels up to 7.0 dBm. Higher input levels will saturate the detector and preamplifier and may distort the data output.

13) Reflections back into the laser transmitter will increase the noise of the transmitter and potentially decrease the links optical margin and performance. This is a characteristic of all laser transmitters. It is recommended that steps be taken (such as PC polish or Super PC polish of connectors or the use of an index matching gel) to minimize backreflections. The link will meet BER specifications for reflection levels less than -25 dB. The higher output power transmitter models can tolerate a maximum backreflection of -35 dB

14) Figure 4 shows the connections of the transmitter for single-ended and differential operation. In the single-ended case, the "- DATA IN" line, Pin 4, is connected to V_{BB} which is present on Pin 7. Also, a 100 Ohm (150 Ohm) resistor should be connected from Pin 4 to ground and bypassed with a 1000 pF to .01 F capacitor. The 100 Ohm (150 Ohm) resistor is required to reduce the current drawn by the internal 50 Ohm (75 Ohm) resistor that is connected from the "- DATA IN" line to -2 Volts. The 100 Ohm (150 Ohm) resistor will see a current of about 13.5 mA almost exactly matching the current drawn by the internal 50 Ohm (75 Ohm) resistor. Performance in the single-ended configuration can fall short of the published specifications if the input signal is not very clean.

15) Figure 5 shows the connection of the receiver in the single-ended and differential modes. The receiver may be used for single-ended operation; however, both outputs must be terminated 50 Ohms (75 Ohms) to -2.0 V. The -2.0 Volts should be bypassed very near the 50 Ohm (75 Ohm) terminating resistors. Performance in the single-ended configuration can fall short of the published specifications if the PCB layout is not very clean. The location of the 50 Ohm (75 Ohm) terminating resistor on the unused output is critical to good operation. The best results are usually obtained by making the run lengths of the +D and -D outputs identical and putting the terminating resistors in the same location.

16) The Loss-of-Signal (LOS) flag on the receiver is an open collector output. It must be pulled high externally if a voltage output is required. This output can sustain 12 Volts maximum in the off condition and can handle 60 mA maximum when turned on. The output state is as follows:

Low - Input light level is adequate for proper link operation. High - Input light level is too low for proper link operation

17) Both the 2666 transmitter and receiver require minimal external components for proper operation. Typical application circuits are shown in Figures 4 and 5. It is important that signal output lines be properly terminated into 50 Ohms (75 Ohms). A 50 Ohm (75 Ohm) resistor to -2.0 Volts is recommended. The use of 50 Ohm (75 Ohm) signal paths is critical for proper operation. It is good practice to bypass power connections to the modules using good quality high-frequency capacitors.

18) A moving air flow environment is recommended for these modules. Each module can dissipate up to 0.45 W (Transmitter) and 0.77 W (Receiver) at +25 ℃ and requires adequate cooling for proper operation. The case operating temperature must be less than 50 ℃ at all times. Figure 1 below shows the thermal resistance of the case in a moving air environment. An airflow of 400 linear feet per minute (LFPM) lowers the case thermal resistance to 5 ℃/Watt allowing operation in ambient temperatures to 45 ℃.

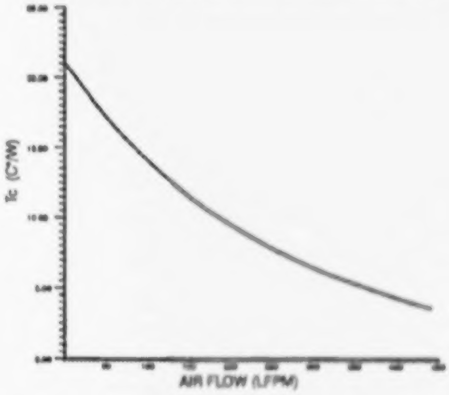


Figure 1 - Thermal Resistance - Package to Air

19) Reliability calculations are performed in accordance with MIL-HDBK-217F. A ground benign environment was chosen. All failure data is derived from MIL-HDBK-217F except the laser and detector failure data. The laser and detector failure rate is based on manufacturer's data.

20) Because the transmitter uses a single-mode fiber pigtail and the receiver uses a multimode 50/125 µm graded-index pigtail, the Model 2666 is compatible with single-mode fiber and multimode fiber. Distances to approximately 1 km are achievable at the highest data rates and over 5 km at rates below 500 Mb/s. Contact the factory for additional details.

21) The transmitter and receiver modules can be configured for single-ended or differential operation. See notes 14 and 15 for details. The link is optimized for use with 50 Ohm (75 Ohm) impedance connections. The receiver outputs have an output impedance of approximately 8 Ohms

22) An asymmetrical pattern was chosen to make it impossible to insert a module backwards and to prevent a transmitter from being installed where a receiver is required. For this feature to be effective, the printed

circuit board (PCB) should not have holes drilled where pins are omitted.

23) Be cautious when running traces under the modules. It is likely that the box will short to the traces. The box is grounded. A ground plane is recommended under the modules.

24) The receiver has a "SIGNAL STRENGTH" output on pin 7. This pin can drive a MAXIMUM load of 100 kOhms. No smaller resistance is allowed. The output on this pin gives an indication of how much light is reaching the detector. The transfer function is approximately:

$P_{in} = 0.381 \cdot e^{3.114 \cdot V_{ss}}$; where V_{ss} is typically 1.20-1.90, P_{in} is in μW

Older models of the receiver use a different function as given below. Contact Force, Inc. for details.

$P_{in} = -.798 * (V_{ss})^2 + .865 * V_{ss} - .238$; where V_{ss} is typically 0.38-0.49; P_{in} is in dBm

25) Figures 6 through 10 show typical eye diagrams of the link at data rates of 100 Mb/s, 700 Mb/s, 1.26 Gb/s and 1.7 Gb/s at low and maximum optical loss. Figure 14 shows the measurement of all waveform parameters with a square wave input at 350 MHz. This corresponds to 700 Mb/s. While the performance shown in Figure 10 is not guaranteed, it is typical of the 2666 links. An even more impressive demonstration is shown in Figure 11. In this Figure, a 2666 link is operating at a data rate of 2.0 Gb/s. The optical loss in this case was about 6 dB. The link was found to operate error-free up to about 10 dB optical loss.

26) See Application Note 102 and Application Note 103 for additional information.

UNIT OUTLINE DRAWINGS

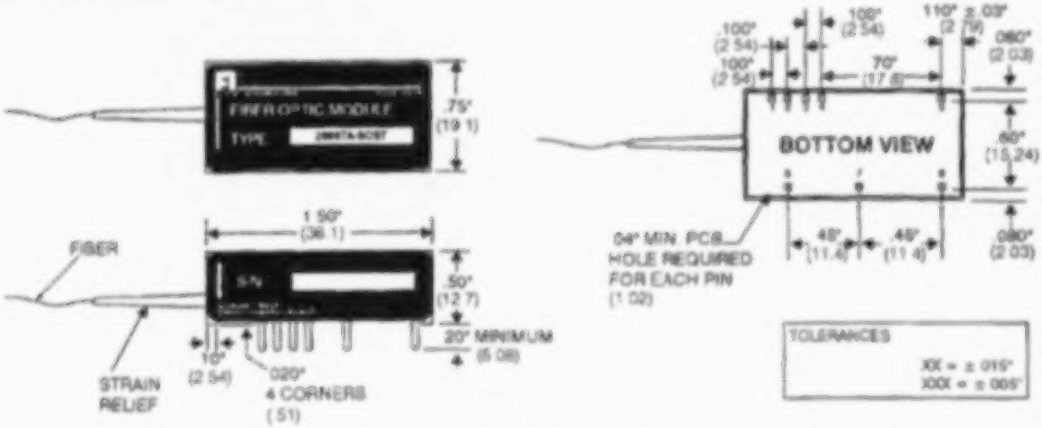

FIBER OPTIC MODULE
TYPE
.75"
(19.1)
1.50"
(38.1)
FIBER
S/N
.50"
(12.7)
.20" MINIMUM
(5.08)
.10"
(2.54)
.020"
4 CORNERS
(.51)
STRAIN
RELIEF
.100"
(2.54)
.100"
(2.54)
.100"
(2.54)
.110" ± .03"
(2.79)
.080"
(2.03)
.70"
(17.8)
BOTTOM VIEW
.60"
(15.24)
.04" MIN. PCB
HOLE REQUIRED
FOR EACH PIN
(1.02)
.45"
(11.4)
.45"
(11.4)
.080"
(2.03)
TOLERANCES
XX = ± .015"
XXX = ± .005"

Figure 2 - Model 2666 Transmitter
(Dimensions in parentheses are in millimeters.)

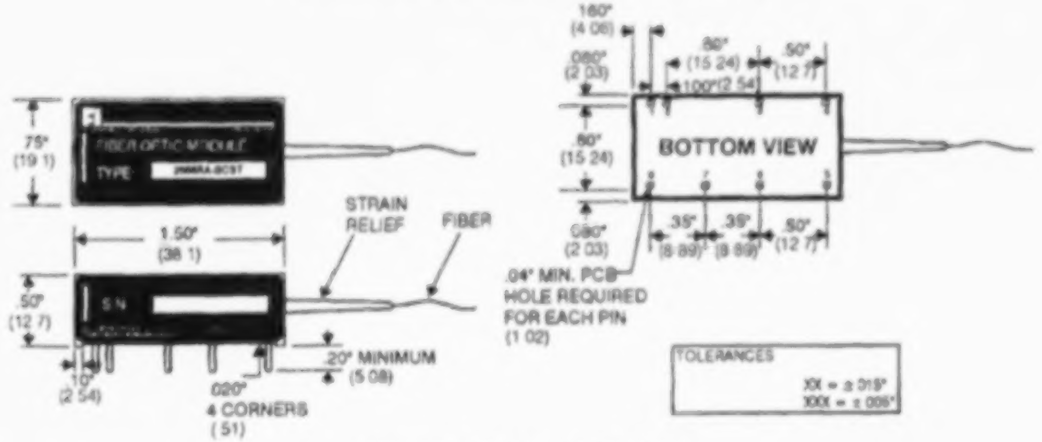

.75"
(19.1)
FIBER OPTIC MODULE
TYPE
1.50"
(38.1)
STRAIN
RELIEF
FIBER
.50"
(12.7)
S/N
.10"
(2.54)
.020"
4 CORNERS
(.51)
.20" MINIMUM
(5.08)
.160"
(4.06)
.080"
(2.03)
.60"
(15.24)
.100"(2.54)
.50"
(12.7)
.60"
(15.24)
BOTTOM VIEW
.080"
(2.03)
.35"
(8.89)
.35"
(8.89)
.50"
(12.7)
.04" MIN. PCB
HOLE REQUIRED
FOR EACH PIN
(1.02)
TOLERANCES
XX = ± .015"
XXX = ± .005"

Figure 3 - Model 2666 Receiver
(Dimensions in parentheses are in millimeters.)

circuit board (PCB) should not have holes drilled where pins are omitted.

23) Be cautious when running traces under the modules. It is likely that the box will short to the traces. The box is grounded. A ground plane is recommended under the modules.

24) The receiver has a "SIGNAL STRENGTH" output on pin 7. This pin can drive a MAXIMUM load of 100 kOhms. No smaller resistance is allowed. The output on this pin gives an indication of how much light is reaching the detector. The transfer function is approximately:

$P_{IN} = 0.381 \cdot e^{3.114 \cdot V_{SS}}$; where V_{SS} is typically 1.20-1.90; P_{IN} is in μW

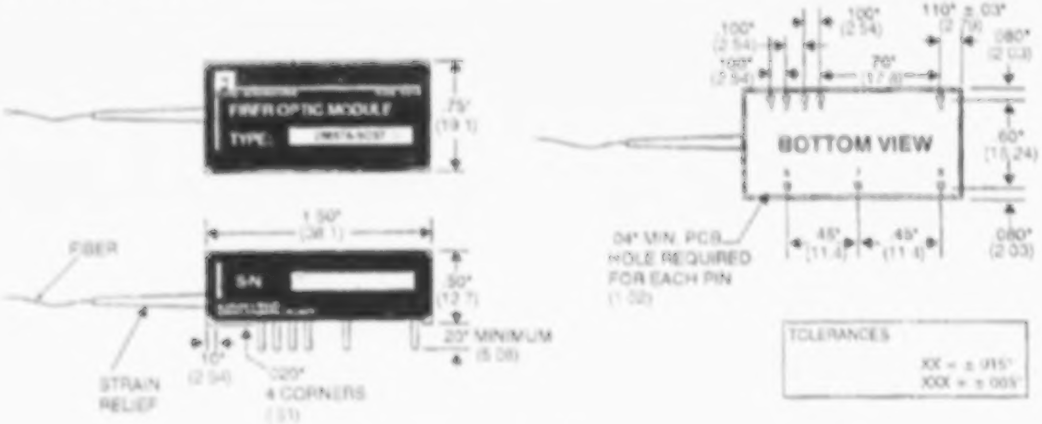
Older models of the receiver use a different function as given below. Contact Force, Inc. for details.

$P_{IN} = -798 \cdot (V_{SS})^2 + 865 \cdot V_{SS} - 238$; where V_{SS} is typically 0.38-0.49; P_{IN} is in dBm

25) Figures 6 through 10 show typical eye diagrams of the link at data rates of 100 Mb/s, 700 Mb/s, 1.26 Gb/s and 1.7 Gb/s at low and maximum optical loss. Figure 14 shows the measurement of all waveform parameters with a square wave input at 350 MHz. This corresponds to 700 Mb/s. While the performance shown in Figure 10 is not guaranteed, it is typical of the 2666 links. An even more impressive demonstration is shown in Figure 11. In this Figure, a 2666 link is operating at a data rate of 2.0 Gb/s. The optical loss in this case was about 6 dB. The link was found to operate error-free up to about 10 dB optical loss.

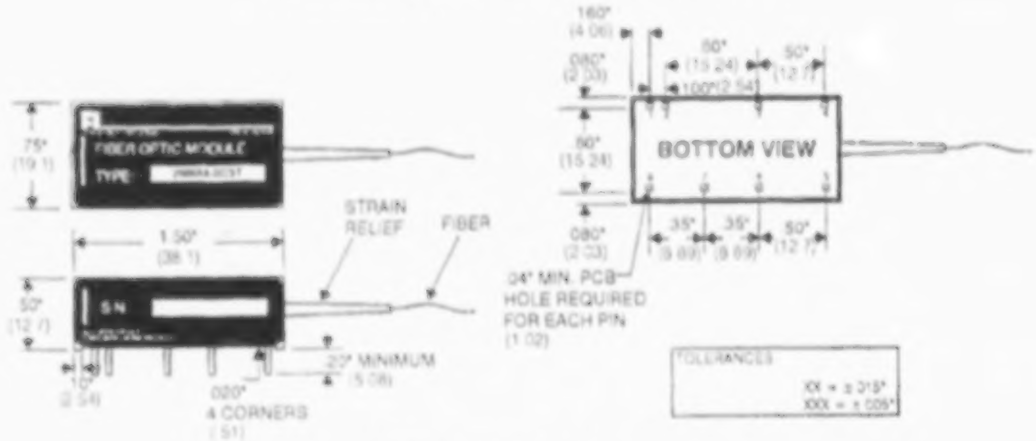
26) See Application Note 102 and Application Note 103 for additional information.

UNIT OUTLINE DRAWINGS



FIBER OPTIC MODULE
TYPE:
.75" (19.1)
1.50" (38.1)
FIBER
S/N
.50" (12.7)
STRAIN RELIEF
.10" (2.54)
.020" 4 CORNERS (.51)
.20" MINIMUM (5.08)
.100" (2.54)
.100" (2.54)
.100" (2.54)
.110" ± .03" (2.79)
.080" (2.03)
.70" (17.8)
BOTTOM VIEW
.60" (15.24)
.04" MIN. PCB HOLE REQUIRED FOR EACH PIN (1.02)
.45" (11.4)
.45" (11.4)
.080" (2.03)
TOLERANCES
.XX = ± .015"
.XXX = ± .005"

Figure 2 - Model 2666 Transmitter
(Dimensions in parentheses are in millimeters.)



FIBER OPTIC MODULE
TYPE:
.75" (19.1)
1.50" (38.1)
S/N
.50" (12.7)
.10" (2.54)
.020" 4 CORNERS (.51)
.20" MINIMUM (5.08)
STRAIN RELIEF
FIBER
.160" (4.06)
.080" (2.03)
.60" (15.24)
.50" (12.7)
.100"(2.54)
BOTTOM VIEW
.60" (15.24)
.080" (2.03)
.35" (8.89)
.35" (8.89)
.50" (12.7)
.04" MIN. PCB HOLE REQUIRED FOR EACH PIN (1.02)
TOLERANCES
.XX = ± .015"
.XXX = ± .005"

Figure 3 - Model 2666 Receiver
(Dimensions in parentheses are in millimeters.)

CONNECTIONS

Connection	Connector Type	Pin #	Transmitter Function	Receiver Function
Power and signal connections	Solder pins for direct PCB mount. (Wave soldering is not recommended for theses parts. Pins are 0 025" square, gold-plated. A 0.040" hole is recommended on the PCB)	1	Ground	-Data Out
		2	+Data In	+Data Out
		3	V_{TT} (-2.0 V_{DC})	Ground
		4	-Data In	V_{EE} (-5.2 V_{DC})
		5	Ground	Loss-of-Signal Flag
		6	V_{EE} (-5.2 V_{DC})	V_{CC} (+5.0 V_{DC})
		7	V_{BB} (ref out)	Signal Strength
		8	Ground	Ground
Optical connection.	FC, SC (Standard), and ST™ options available.		Standard transmitter has a 30" SM fiber pigtail	Standard receiver has a 18" 50/125 µm fiber pigtail.

APPLICATION DIAGRAMS

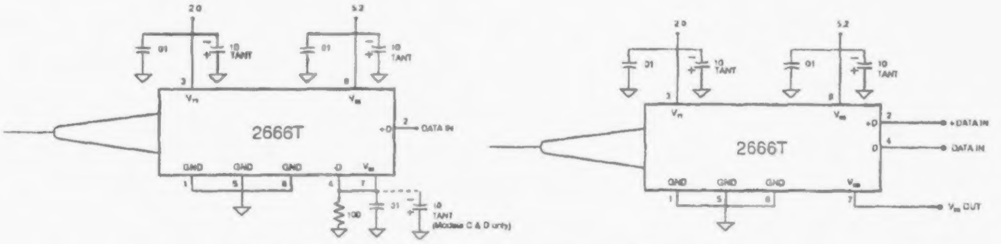

2666T
2.0
5.2
.01
10 TANT
DATA IN
GND
100
10 TANT (Modules C & D only)
+DATA IN
DATA IN
V_{BB} OUT

Figure 4 - Typical Application Circuit - Transmitter

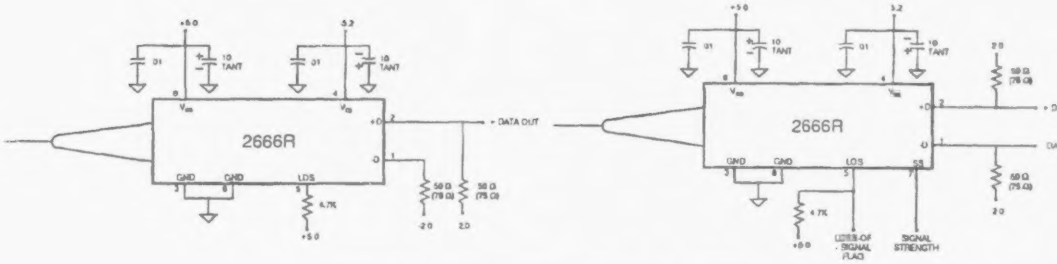
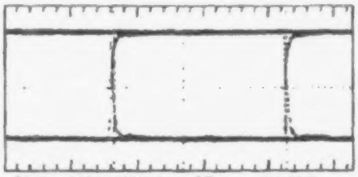
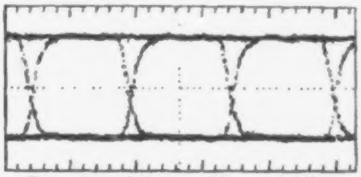

2666R
+5.0
5.2
.01
10 TANT
+DATA OUT
DATA OUT
GND
LOS
SS
4.7K
50 Ω (75 Ω)
-2.0
2.0
LOSS-OF-SIGNAL FLAG
SIGNAL STRENGTH

Figure 5 - Typical Application Circuit - Receiver



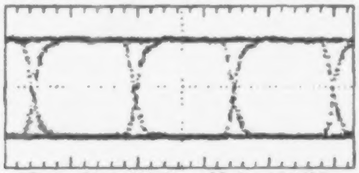
Ch 3 = 200 0 mVolts/div Offset = -1 301 Volts
Timebase = 2 00 ns/div Delay = 57 8260 ns
Delta V = 0 0 Volts
Vmarker1 = -1 3750 Volts Vmarker2 = -1 3750 Volts
Delta T = 98000 ns

Figure 6 - Eye Diagram: 100 Mb/s; 13 dB Optical Loss



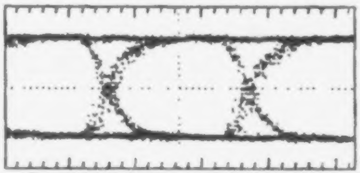
Ch 1 = 200 0 mVolts/div Offset = -1 245 Volts
Timebase = 500 ps/div Delay = 34 8300 ns

Figure 7 - Eye Diagram: 700 Mb/s; Low Optical Loss



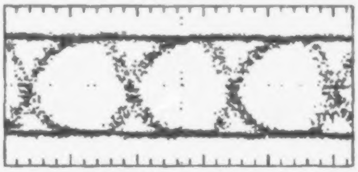
Ch 1 = 200 0 mVolts/div Offset = -1 241 Volts
Timebase = 500 ps/div Delay = 34 8300 ns

Figure 8 - Eye Diagram: 700 Mb/s; 13 dB Optical Loss



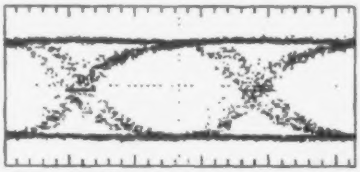
Ch 1 = 200 0 mVolts/div Offset = -1.245 Volts
Timebase = 200 ps/div Delay = 33 8880 ns

Figure 9 - Eye Diagram: 1.26 Gb/s; 13 dB Optical Loss



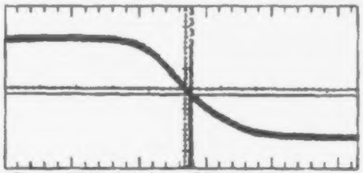
Ch 1 = 200 0 mVolts/div Offset = -1.245 Volts
Timebase = 200 ps/div Delay = 33 6120 ns

Figure 10 - Eye Diagram: 1.7 Gb/s; 13 dB Optical Loss



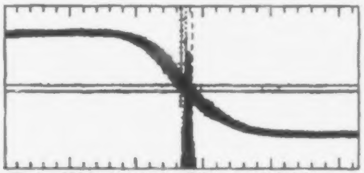
Ch 1 = 200 0 mVolts/div Offset = -1 245 Volts
Timebase = 100 ps/div Delay = 38 9320 ns

Figure 11 - Eye Diagram: 2.0 Gb/s; 6 dB Optical Loss



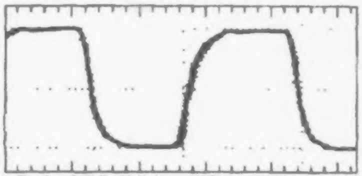
Ch 1 = 200 0 mVolts/div Offset = -1 301 Volts
Timebase = 100 ps/div Delay = 57 8250 ns
DeltaWindow = 0 0 Volts
Window 1 = -1 3000 Volts Window 2 = -1 3750 Volts

Figure 12 - Random Jitter, Low Optical Loss; s=3.4 ps



Ch 1 = 200 0 mVolts/div Offset = -1 245 Volts
Timebase = 100 ps/div Delay = 35 0540 ns
DeltaWindow = 0 0 Volts
Window 1 = -1 3000 Volts Window 2 = -1 3000 Volts

Figure 13 - Random Jitter, 13 dB Optical Loss; s=8.7 ps



Ch 3 = 200 0 mVolts/div Offset = -1 301 Volts
Timebase = 500 ps/div P-P Volts = 1 0375 Volts
Freq = 351 866 MHz Period = 2 8420 ns
Rise Time = 209 ps Fall Time = 218 ps
+ Width = 1 4964 ns - Width = 1 3456 ns
Duty Cycle = 52 65%

Figure 14 - 350 MHz Clock All Waveform Parameters

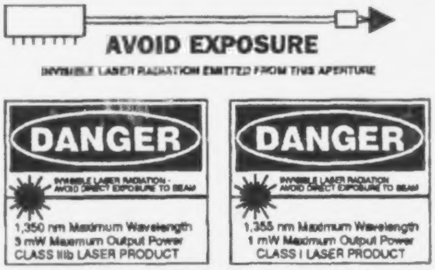
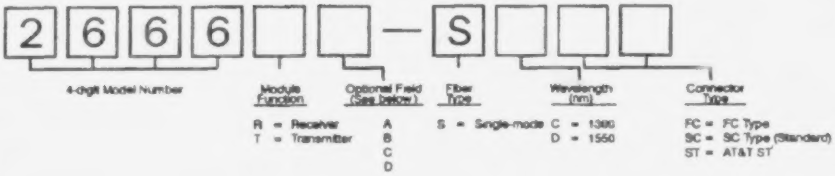

AVOID EXPOSURE
INVISIBLE LASER RADIATION EMITTED FROM THIS APERTURE
DANGER
INVISIBLE LASER RADIATION - AVOID DIRECT EXPOSURE TO BEAM
1,350 nm Maximum Wavelength
3 mW Maximum Output Power
CLASS IIIb LASER PRODUCT
DANGER
INVISIBLE LASER RADIATION AVOID DIRECT EXPOSURE TO BEAM
1,355 nm Maximum Wavelength
1 mW Maximum Output Power
CLASS I LASER PRODUCT

Figure 15 - Laser Warning Labels

ORDERING INFORMATION

PART NUMBERS


2
6
6
6
—
S
4-digit Model Number
Module Function
R = Receiver
T = Transmitter
Optional Field (See below)
A
B
C
D
Fiber Type
S = Single-mode
Wavelength (nm)
C = 1300
D = 1550
Connector Type
FC = FC Type
SC = SC Type (Standard)
ST = AT&T ST

OPTIONAL FIELD

Transmitter			
Option Code	**Operating Wavelength**	**Output Power Level**	**Application**
A	1300 nm	-8 0 dBm Avg Typical	NRZ Data
B	1300 nm	0.0 dBm Avg. Typical	NRZ Data
C	1300 nm	-8.0 dBm Avg. Typical	Digital Video
D	1300 nm	0.0 dBm Avg Typical	Digital Video
A	1550 nm	-8.0 dBm Avg. Typical	NRZ Data
B	1550 nm	-3.0 dBm Avg Typical	NRZ Data
C	1550 nm	-8.0 dBm Avg. Typical	Digital Video
D	1550 nm	-3.0 dBm Avg. Typical	Digital Video

Receiver		
Option Code	**Sensitivity**	**Application**
A	-21.0 dBm Minimum	NRZ Data
C	-21.0 dBm Minimum	Digital Video

EVALUATION BOARDS

Force, Incorporated offers evaluation boards for the transmitters and receivers. These boards feature solder terminal power inputs and SMA connectors for electrical data I/O The boards include all required regulators for the receiver and transmitter to operate. The boards may be purchased with machined sockets or without sockets for direct soldering. Part numbers are as follows:

Module Type Board	Part Number	Comments
Transmitter Evaluation Board	2666T-EVAL-SK	Provided with machined sockets.
Receiver Evaluation Board	2666R-EVAL-SK	Provided with machined sockets.
NOTE Contact the factory for digital video evaluation boards		

Force, Incorporated reserves the right to make changes to the product described in this document in the interest of product improvement.
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TECHNICAL BULLETIN

TB 195A

DTV*Linx*®

SM1-622 Mb/s
FIBER OPTIC LINK

MODEL 2753

The Force, Incorporated DTV*Linx*® Model 2753 Single-mode 1-622 Mb/s Fiber Optic Link provides a high-quality, low cost system for transferring high-speed digital video or data with complete EMI immunity via fiber optics. The Model 2753 handles data rates from 1 Mb/s to 622 Mb/s. The units offer excellent performance up to 30 dB optical loss using 9/125 micron single-mode fiber. There are no user adjustments required over the full optical loss range.

State-of-the-art 1310 nm or 1550 nm electro-optics are incorporated to achieve the performance levels cited. The parts may also be used with ECL logic levels (positive or negative). The units are built in a rugged enclosure, and options are available for rack-mounting one or more units in 1RU, 3RU and 6RU configurations.

Transmission path lengths, using 9/125 μm fiber, are greater than 50 km (0.5 dB/km @ 1310 nm) or 100 km (0.25dB/km @ 1550 nm).

For higher speeds and/or multiple channel applications, contact Force, Inc. for information on other **DTV***Linx*® products such as the Model 2953 (up to 1.485 Gb/s – TB196) or Model 2822 (up to 400 Mb/s – TB152) or the **Comlux**® line of TDM multichannel trunking products (up to 3.1 Gb/s). For multimode fiber applications the Model 2853 (TB188) is recommended.

FEATURES

- Data Rate Capability to 622 Mb/s
- Pathological Test Code Compliant
- 1310 nm/1550 nm Operation
- Up to 30 dB Optical Loss Range
- SC Optical Connector Standard
- FC Optical Connector Option Available
- Mounting Configurations
  - – Compact Stand-alone
  - – 1RU 19" EIA Rack-mount
  - – 3RU Powered Chassis
  - – 6RU Redundant Powered Chassis

APPLICATIONS

- CCIR601
- SMPTE 259M (SDI) & 305M (SDTI) Level A, B, C & D Video Transmission (144, 177, 270, and 360 Mb/s)
- SONET, SDH, ATM, MPEG, & SMPTE 310M Transmission
- Intra-studio Distribution
- STL Link
- Switched Digital Video Networks
- Compressed Video Transmission

Fi Force, Incorporated
Fiber Optics and Electronics

825 Park Street (PO Box 2045)
Christiansburg, VA 24073
(800) 732-5252 • (540) 382-0462
Fax: (540) 381-0392

E-Mail: force@forceinc.com
Web Page www.forceinc.com

OPTICAL AND ELECTRICAL CHARACTERISTICS: @ 25°C, 9/125 μM FIBER

	Min.	Typ.	Max.	Units	Notes
NRZ Data Rate	1.0		622	Mb/s	
Optical Loss Range (1310 nm @ 270 Mb/s)	25	27	29	dB	1
Optical Loss Range (1550 nm @ 270 Mb/s)	26	29	30	dB	1
Operating Wavelength (Tx)	1270	1310	1330	nm	
Spectral Width (FWHM – 1310 nm Model)		2	5	nm	
Operating Wavelength (Tx)	1520	1550	1570	nm	
Spectral Width (FWHM – 1550 nm Model)			0.5	nm	
Optical Output Power (1310 nm Model)	-3.0	-2.0	+0.5	dBm	2
Optical Output Power (1550 nm Model)	-2.0	0	+2.0	dBm	2
Optical Overload (Rx)	-4.0		-2.0	dBm	
Optical Sensitivity (Rx @ 1-400 Mb/s)	-28			dBm	3, 4
Optical Sensitivity (Rx @ 622 Mb/s)	-23			dBm	3, 4
Input/Output Impedance		75		Ohms	5
BER			10^{-9}		4
Power Supply Voltage	+12		+15	V_{DC}	6
Power Supply Current			200	mA	

PHYSICAL AND ELECTRICAL CHARACTERISTICS

	Min.	Typ.	Max.	Units	Notes
Weight		10.0		oz.	
		283.5		g	
Dimensions	5.75 x 2.95 x1.12			in	
	146.05 x 74.93 x 28.45			mm	
Operating Temperature Range	-20		+60	°C	
Storage Temperature Range	-40		+100	°C	
Humidity	0		95	%	7

SPECIFICATION NOTES

1) The unit may require optical attenuation of up to 4.5 dB at 1310 nm and 6 dB at 1550 nm to prevent overload. The link uses 9/125 μm fiber.
2) The transmitter is equipped with a tri-colored laser indicatior LED. When the laser is performing correctly the LED will be green. When the laser experiences an excess of modulation current, the LED will be yellow, and when the laser experiences excess bias current, the LED will be red. Since the LED is always lit, it also serves as a positive indication that the unit is receiving power.
3) The receiver is equipped with a tri-colored loss-of-signal indicator LED. When the unit is receiving sufficient optical power, the LED is green. When the optical input power has dropped to insufficient levels, the LED is yellow. When the optical input power has exceeded the proper input level, the LED is red. Because the LED is always lit, it also serves as a positive indication that the unit is receiving power.
4) Sensitivity and BER figures are a function of data rate. Testing of random pairs demonstrates sensitivity figures at or below -28.0 dBm for data rates of 1 Mb/s to 400 Mb/s. These figures derate to -22 dBm or better at a data rate of 622 Mb/s (OC12).
5) The ECL input/ output levels are optimized for 75 Ohms.
6) The supply voltage is DC ranging from +12 Volts to +15 Volts. Operation at higher voltage is possible, but the upper operating temperature of the part should be derated 5°C for every Volt over +15 Volts. The units will tolerate moderate amounts of ripple, but this should not exceed 0.5 Volts peak-to-peak. It is critical that the supply voltage NEVER drops below +12 Volts for any part of the waveform. Voltages below +12 Volts will cause the internal voltage regulators to lose regulation which will disrupt the operation of the unit and cause unpredictable results.
7) Humidity is RH non-condensing.
8) The bottom of the box serves as a heat sink. It is imperative that good thermal contact be provided between the bottom of the box and the external heat sink. Heat conductive pads are recommended to improve thermal conductivity.

CONNECTIONS

Connector Number	Connector Type	Connector Function		
		Pin	Transmitter Function	Receiver Function
J1	Weidmuller 4-Pin Mating adapter provided.	J1-1	Power	Power
		J1-2	Ground	Ground
		J1-3	Laser Status	Optical Signal Status
		J1-4	Not Connected	Not Connected
J2	BNC, 75 Ohms		Data Input	Data Output
J3	SC Connector Standard FC Connector Optional		Optical Output	Optical Input

UNIT OUTLINE DRAWINGS

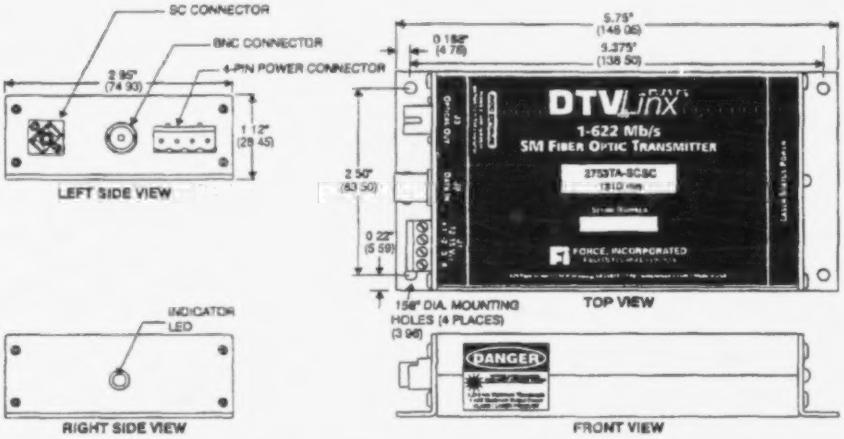

SC CONNECTOR
BNC CONNECTOR
4-PIN POWER CONNECTOR
2.95"
(74.93)
1.12"
(28.45)
LEFT SIDE VIEW
INDICATOR
LED
RIGHT SIDE VIEW
5.75"
(146.05)
0.188"
(4.78)
5.375"
(136.50)
2.50"
(63.50)
0.22"
(5.59)
.156" DIA. MOUNTING
HOLES (4 PLACES)
(3.96)
DTVLinx
1-622 Mb/s
SM FIBER OPTIC TRANSMITTER
2753TA-SCSC
1310 nm
FORCE, INCORPORATED
TOP VIEW
DANGER
FRONT VIEW

Figure 1 - Model 2753 Single-mode Transmitter
Receiver configuration is identical.
(Dimensions in parentheses are in millimeters)

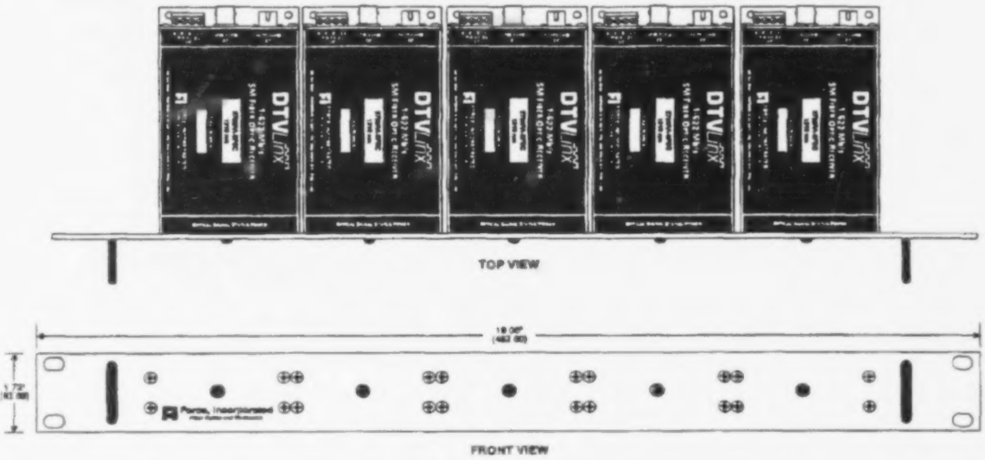

DTVLinx
TOP VIEW
19.00"
(482.60)
1.72"
(43.69)
Force, Incorporated
FRONT VIEW

Figure 2 - Five Model 2753 Receivers on a 1RU Rack-mount Panel
See IOM2800 for complete mounting instructions.
(Dimensions in parentheses are in millimeters.)

CONNECTIONS

Connector Number	Connector Type	Connector Function		
		Pin	Transmitter Function	Receiver Function
J1	Weidmuller 4-Pin Mating adapter provided	J1-1	Power	Power
		J1-2	Ground	Ground
		J1-3	Laser Status	Optical Signal Status
		J1-4	Not Connected	Not Connected
J2	BNC, 75 Ohms		Data Input	Data Output
J3	SC Connector Standard FC Connector Optional		Optical Output	Optical Input

UNIT OUTLINE DRAWINGS

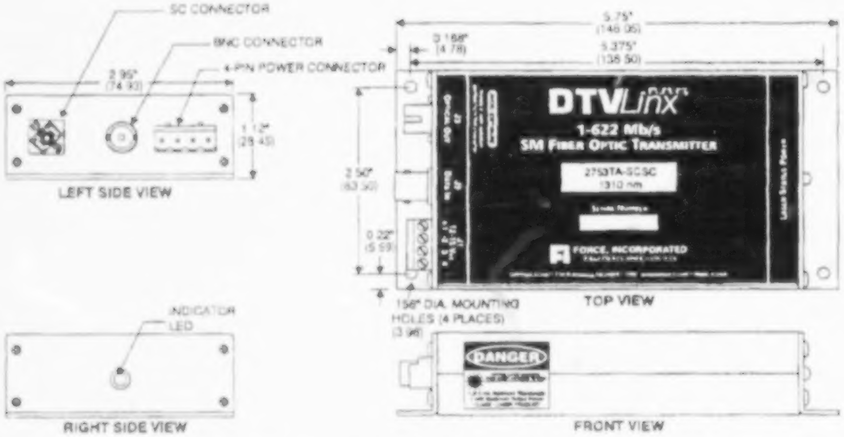

SC CONNECTOR
BNC CONNECTOR
4-PIN POWER CONNECTOR
2.95"
(74.93)
1.12"
(28.45)
LEFT SIDE VIEW
5.75"
(146.05)
0.188"
(4.78)
5.375"
(136.50)
2.50"
(63.50)
0.22"
(5.59)
DTVLinx
1-622 Mb/s
SM FIBER OPTIC TRANSMITTER
2753TA-SCSC
1310 nm
FORCE, INCORPORATED
.156" DIA. MOUNTING
HOLES (4 PLACES)
(3.96)
TOP VIEW
INDICATOR
LED
RIGHT SIDE VIEW
DANGER
FRONT VIEW

Figure 1 - Model 2753 Single-mode Transmitter
Receiver configuration is identical.
(Dimensions in parentheses are in millimeters)

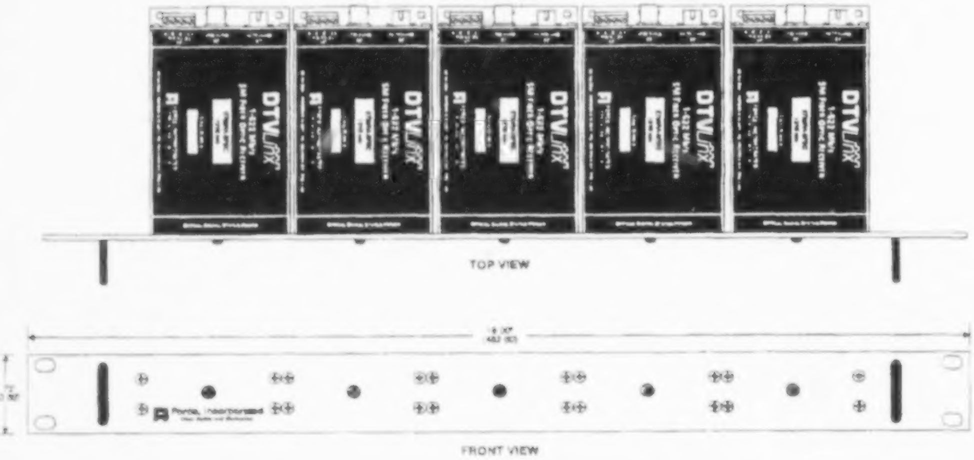
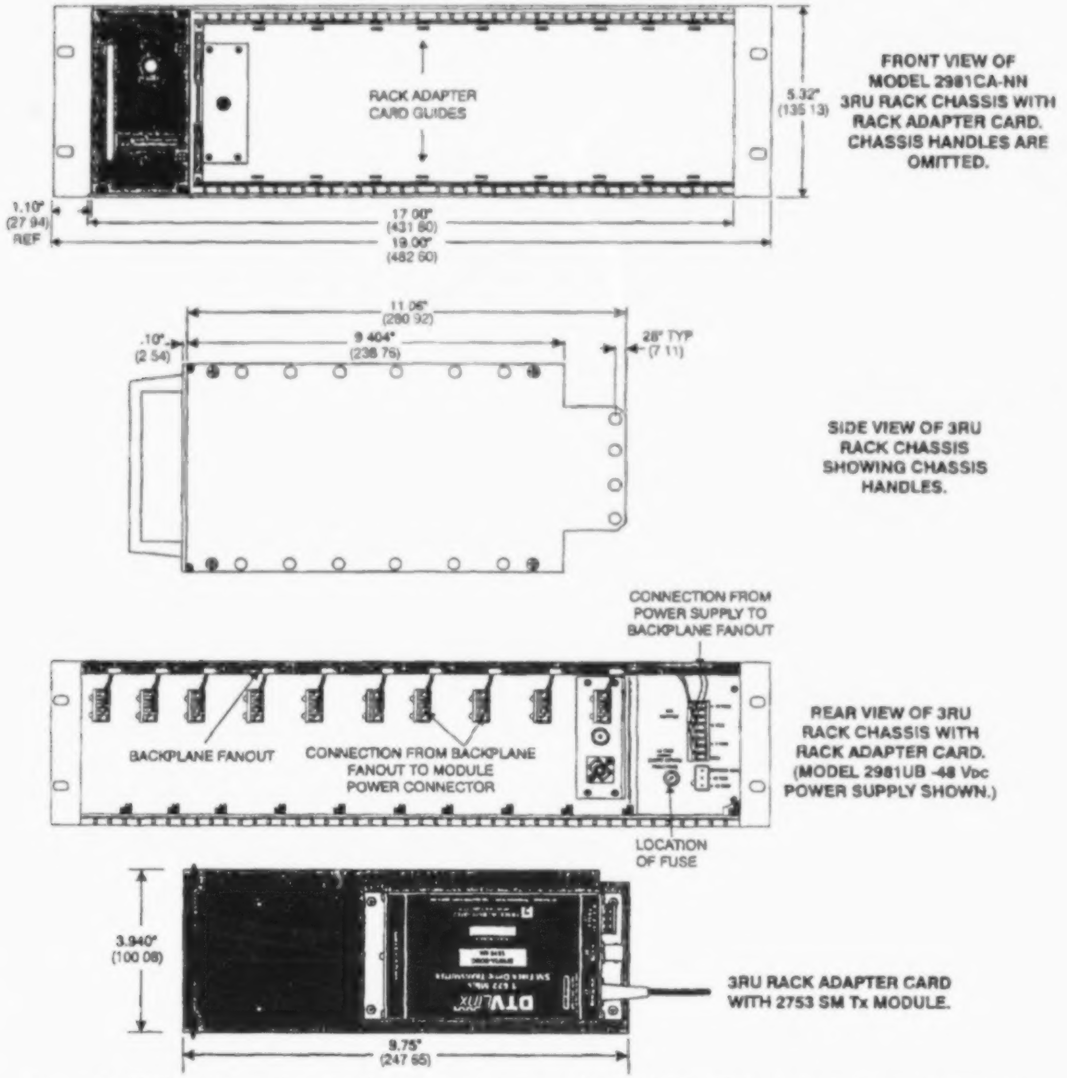

DTVLinx
TOP VIEW
Force, Incorporated
FRONT VIEW

Figure 2 - Five Model 2753 Receivers on a 1RU Rack-mount Panel
See IOM2800 for complete mounting instructions.
(Dimensions in parentheses are in millimeters.)


RACK ADAPTER
CARD GUIDES
5.32"
(135.13)
1.10"
(27.94)
REF
17.00"
(431.80)
19.00"
(482.60)
11.06"
(280.92)
.10"
(2.54)
9.404"
(238.76)
.28" TYP
(7.11)
CONNECTION FROM
POWER SUPPLY TO
BACKPLANE FANOUT
BACKPLANE FANOUT
CONNECTION FROM BACKPLANE
FANOUT TO MODULE
POWER CONNECTOR
LOCATION
OF FUSE
3.940"
(100.08)
9.75"
(247.65)
DTVLinx

FRONT VIEW OF MODEL 2981CA-NN 3RU RACK CHASSIS WITH RACK ADAPTER CARD. CHASSIS HANDLES ARE OMITTED.

SIDE VIEW OF 3RU RACK CHASSIS SHOWING CHASSIS HANDLES.

REAR VIEW OF 3RU RACK CHASSIS WITH RACK ADAPTER CARD. (MODEL 2981UB -48 Vdc POWER SUPPLY SHOWN.)

3RU RACK ADAPTER CARD WITH 2753 SM Tx MODULE.

Figure 3 - 3RU Configuration: See TB186 for details on the 3RU EIA 19" Basic Powered Rack Chassis. (Dimensions in parentheses are in millimeters.)

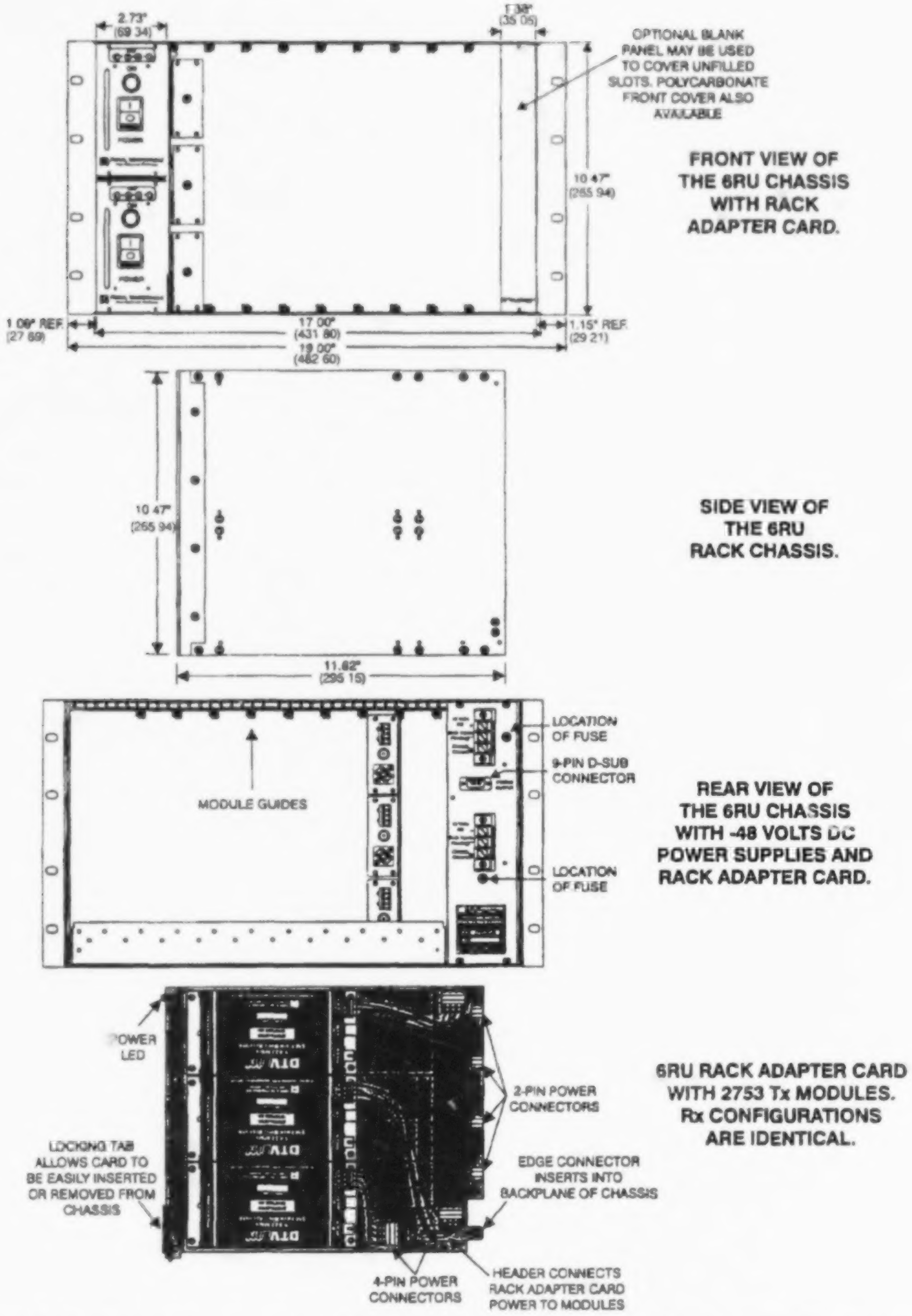
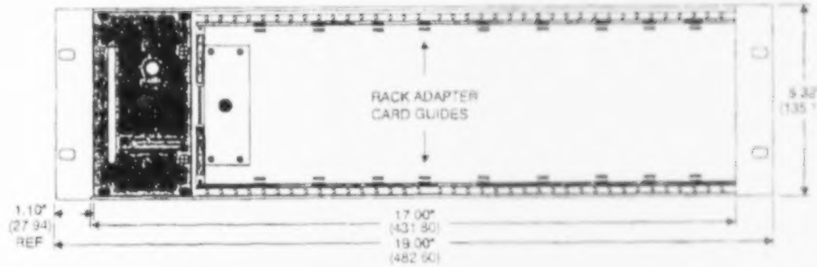
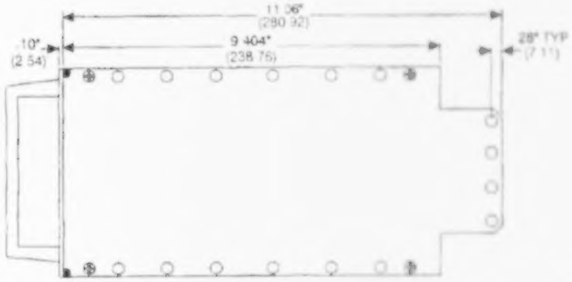

2.73"
(69.34)
1.38"
(35.05)
OPTIONAL BLANK PANEL MAY BE USED TO COVER UNFILLED SLOTS. POLYCARBONATE FRONT COVER ALSO AVAILABLE
10.47"
(265.94)
FRONT VIEW OF THE 6RU CHASSIS WITH RACK ADAPTER CARD.
1.09" REF.
(27.69)
17.00"
(431.80)
19.00"
(482.60)
1.15" REF.
(29.21)
10.47"
(265.94)
11.62"
(295.15)
SIDE VIEW OF THE 6RU RACK CHASSIS.
MODULE GUIDES
LOCATION OF FUSE
9-PIN D-SUB CONNECTOR
LOCATION OF FUSE
REAR VIEW OF THE 6RU CHASSIS WITH -48 VOLTS DC POWER SUPPLIES AND RACK ADAPTER CARD.
POWER LED
LOCKING TAB ALLOWS CARD TO BE EASILY INSERTED OR REMOVED FROM CHASSIS
2-PIN POWER CONNECTORS
EDGE CONNECTOR INSERTS INTO BACKPLANE OF CHASSIS
4-PIN POWER CONNECTORS
HEADER CONNECTS RACK ADAPTER CARD POWER TO MODULES
6RU RACK ADAPTER CARD WITH 2753 Tx MODULES. Rx CONFIGURATIONS ARE IDENTICAL.

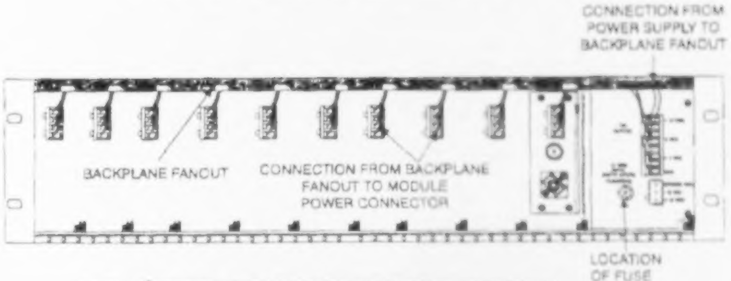
Figure 4 - 6RU Configuration: See TB144 for details on the 6RU EIA 19" Deluxe Powered Rack Chassis. (Dimensions in parentheses are in millimeters.)


RACK ADAPTER
CARD GUIDES
5.33"
(135.13)
1.10"
(27.94)
REF
17.00"
(431.80)
19.00"
(482.60)

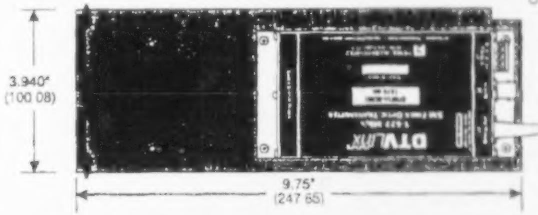
FRONT VIEW OF MODEL 2981CA-NN 3RU RACK CHASSIS WITH RACK ADAPTER CARD. CHASSIS HANDLES ARE OMITTED.


11.06"
(280.92)
.10"
(2.54)
9.404"
(238.76)
.28" TYP
(7.11)

SIDE VIEW OF 3RU RACK CHASSIS SHOWING CHASSIS HANDLES.

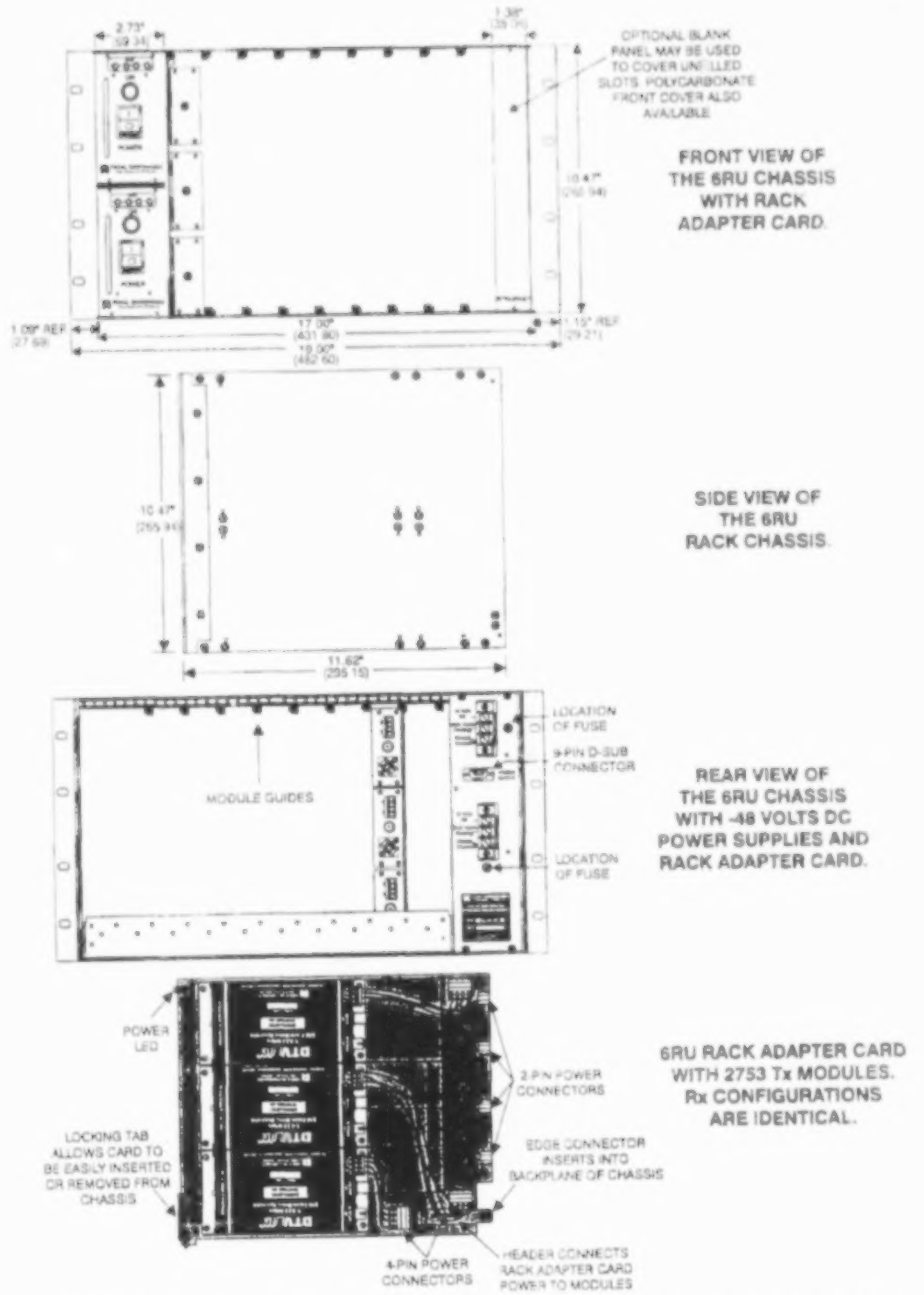

CONNECTION FROM
POWER SUPPLY TO
BACKPLANE FANOUT
BACKPLANE FANOUT
CONNECTION FROM BACKPLANE
FANOUT TO MODULE
POWER CONNECTOR
LOCATION
OF FUSE

REAR VIEW OF 3RU RACK CHASSIS WITH RACK ADAPTER CARD. (MODEL 2981UB -48 Vdc POWER SUPPLY SHOWN.)


3.940"
(100.08)
9.75"
(247.65)
DTVLinx

3RU RACK ADAPTER CARD WITH 2753 SM Tx MODULE.

Figure 3 - 3RU Configuration: See TB186 for details on the 3RU EIA 19" Basic Powered Rack Chassis. (Dimensions in parentheses are in millimeters.)


2.73"
(69.34)
1.38"
OPTIONAL BLANK PANEL MAY BE USED TO COVER UNFILLED SLOTS. POLYCARBONATE FRONT COVER ALSO AVAILABLE
10.47"
1.09" REF
(27.69)
17.00"
(431.80)
19.00"
(482.60)
1.15" REF
(29.21)
10.47"
11.62"
(295.15)
LOCATION OF FUSE
9-PIN D-SUB CONNECTOR
MODULE GUIDES
LOCATION OF FUSE
POWER LED
2-PIN POWER CONNECTORS
LOCKING TAB ALLOWS CARD TO BE EASILY INSERTED OR REMOVED FROM CHASSIS
EDGE CONNECTOR INSERTS INTO BACKPLANE OF CHASSIS
4-PIN POWER CONNECTORS
HEADER CONNECTS RACK ADAPTER CARD POWER TO MODULES

FRONT VIEW OF THE 6RU CHASSIS WITH RACK ADAPTER CARD.

SIDE VIEW OF THE 6RU RACK CHASSIS.

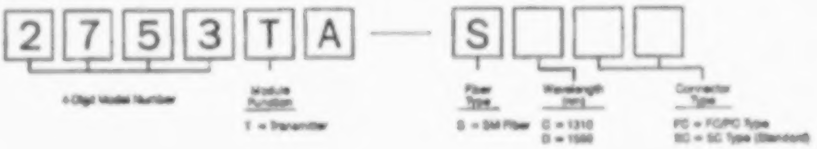
REAR VIEW OF THE 6RU CHASSIS WITH -48 VOLTS DC POWER SUPPLIES AND RACK ADAPTER CARD.

6RU RACK ADAPTER CARD WITH 2753 Tx MODULES. Rx CONFIGURATIONS ARE IDENTICAL.

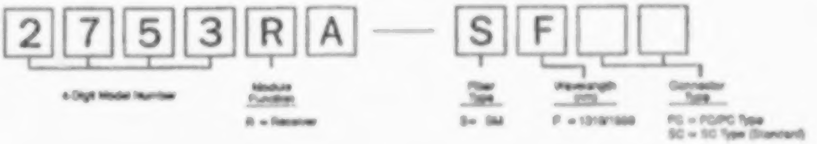
Figure 4 - 6RU Configuration: See TB144 for details on the 6RU EIA 19" Deluxe Powered Rack Chassis. (Dimensions in parentheses are in millimeters.)

ORDERING INFORMATION

TRANSMITTER PART NUMBERS


2 7 5 3 T A — S
4-Digit Model Number
Module Function
T = Transmitter
Fiber Type
S = SM Fiber
Wavelength (nm)
C = 1310
D = 1550
Connector Type
FC = FC/PC Type
SC = SC Type (Standard)

RECEIVER PART NUMBERS


2 7 5 3 R A — S F
4-Digit Model Number
Module Function
R = Receiver
Fiber Type
S= SM
Wavelength (nm)
F = 1310/1550
Connector Type
FC = FC/PC Type
SC = SC Type (Standard)

TX Part Number	Description
2753TA-SCSC	1-622 Mb/s SM Tx, 1310 nm, SC Optical Connector
2753TA-SCFC	1-622 Mb/s SM Tx, 1310 nm FC Optical Connector
2753TA-SDSC	1-622 Mb/s SM Tx, 1550 nm, SC Optical Connector
2753TA-SDFC	1-622 Mb/s SM Tx, 1550 nm, FC Optical Connector
Rx Part Numbers	**Description**
2753RA-SFSC	1-622 Mb/s, SM Rx, 1310/1550 nm, SC Optical Connector
2753RA-SFFC	1-622 Mb/s, SM Rx, 1310/1550 nm, FC Optical Connector

ACCESSORIES

PS170-1	TB043	Wall-mount Power Supply	Provides AC power to the Tx/Rx. (USA Version)
PS170-1/I	TB184	Wall-mount Power Supply	Provides AC power to the Tx/Rx. (International Version)
Model 2800K	IOM2800	1RU Rack-mount Kit	Adapts up to five units to a 1RU panel for use in a standard EIA 19" rack.
Model 2981C	TB186	3RU High, 19" Wide Chassis	Rack-mount Tx/Rx in a 3RU chassis.
Model 2981A	TB186	3RU Rack Adapter Card	Adapt Tx/Rx for use in 3RU chassis.
Model 2981UA	TB186	3RU Chassis Power Supply	Provides 110/220 V_{AC} power to the 3RU chassis.
Model 2981UB	TB186	3RU Chassis Power Supply	Provides -48 V_{DC} power to the 3RU chassis.
Model2781CB	TB144	6RU High, 19" Wide Chassis	Rack-mount Tx/Rx in a 6RU chassis with a Model 2781UA 12-15 V_{DC} power supply.
Model 2781CC	TB144	6RU High, 19" Wide Chassis	Rack-mount Tx/Rx in a 6RU chassis with a Model 2781UD -48 V_{DC} power supply. Model 2781UE -48 V_{DC} power supply.
Model 2781A	TB144	6RU Rack Adapter Card	Adapt Tx/Rx for use in 6RU chassis.
Model 2781UA	TB144	6RU Chassis Power Supply	Provides 12-15 V_{DC} power to the 6RU chassis.
Model 2781UD	TB144	6RU Chassis Power Supply	Provides -48 V_{DC} power to the 6RU chassis.

Force, Incorporated reserves the right to make changes to the product described in this document in the interest of product improvement
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Laser Diode Incorporated
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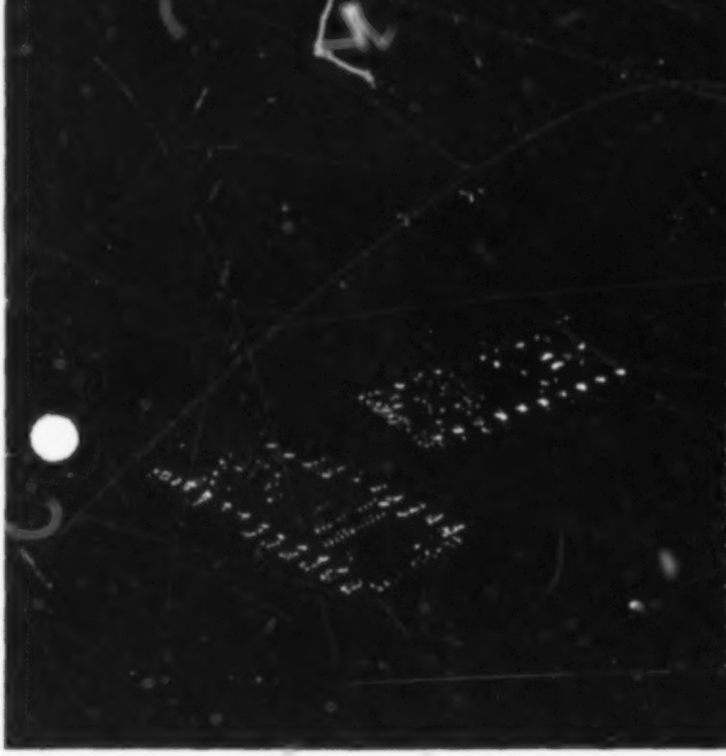
Voice: 732-549-9001, Fax: 732-906-1559
Internet: www.laserdiode.com
e-mail: sales@laserdiode.com

Airpak

transmitter and receiver modules



- Innovative package engineering
- SONET OC1, OC3, OC12
- SDH STM-1, STM-4
- ATM / FDDI
- High-loss budget links
- Up to 800 Mb/s
- 1310 nm and 1550 nm
- PECL or ECL operation
- 20-pin multisource pinout

The Airpak 2000 Series laser transmitters and receivers are full function, high performance digital fiber optic modules. They provide a very cost effective interface between standard ECL and PECL logic families and an optical fiber transmission system.

The innovative application of high quality surface mount technology and a unique integration of optical and electrical components provide performance and quality without the traditional high cost packaging usually associated with optical modules. The savings realized through this approach are significant. The superior reliability engineering on which the modules are based ensures performance in all normal environments and operating conditions.

Laser Diode Incorporated
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Airpak

transmitter and receiver modules

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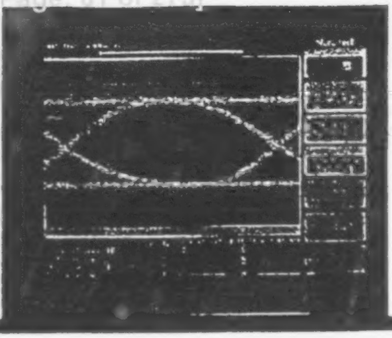


Testing an eye-opening mask to ensure CCITT/ANSI compliance.

Transmitters

...continued on inside overleaf.

Airpak 2000 Series laser transmitters are designed for applications from 1 Mb/s to 800 Mb/s including CCITT SDH and ANSI SONET standard data rates.

The module features a single 5 volt supply operation and a logic interface compatible with either ECL or PECL. The optical source is a low-threshold current, MQW Fabry-Perot laser coupled with a singlemode fiber. The fully self-contained module includes all bias and modulation control circuitry and a disable function to put the laser in standby mode. High- and low-power versions are available for short, intermediate, and long-haul applications. Analog voltage outputs proportional to the laser current and the optical power are available to use for system fault diagnosis. This highly compact transmitter complies with an industry standard, 20-pin, dual-in-line footprint.

Functional Description

High-Speed Driver

The high-speed driver modulates the laser above threshold to maximize speed and minimize pulse-width distortion. The high-speed drive current is controlled by a temperature-sensing network that compensates for the reduction in a laser's power slope at higher operating temperatures by increasing the drive current. The result is that a minimum extinction ratio is maintained over all operating conditions.

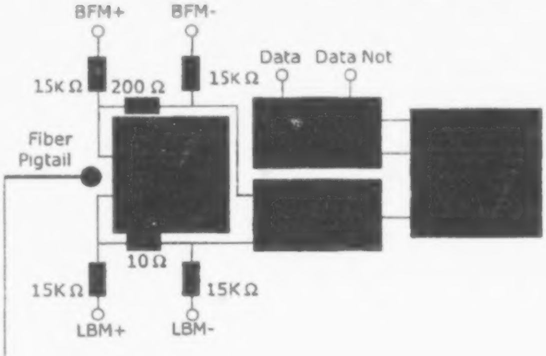
Laser Status Section

The laser's back facet monitor network provides an external differential voltage proportional to the optical power emitted. This monitor is useful in determining whether the transmitter is functioning properly when locating faults along the fiber link.

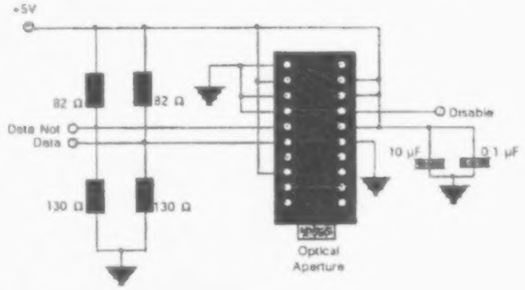
...continued on inside overleaf.

data rates up to 800 Mb/s
low threshold FP laser
wide operating temperature
1310 nm and 1550 nm options
automatic power control
transmitter disable
optical power monitor
laser bias monitor

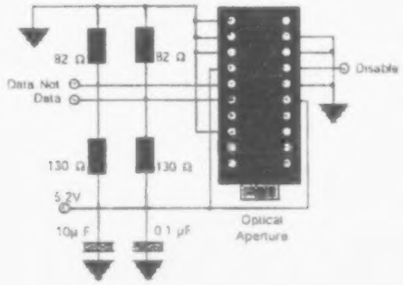
Transmitter Functional Diagram



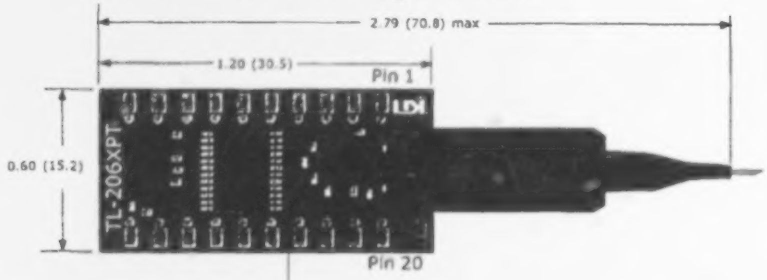
Recommended Transmitter Bias for PECL Applications

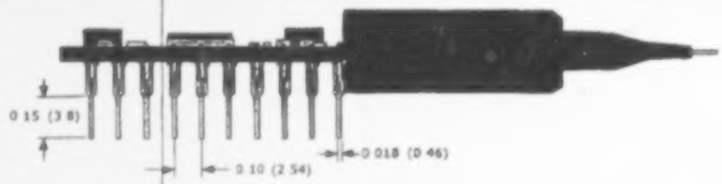


Recommended Transmitter Bias for ECL Applications



Transmitter configuration





The laser's bias current is also monitored with a differential voltage via pins 2 and 4. A variation in this voltage is normal when operating the module at temperatures other than room temperature because the automatic control circuit will increase the bias to maintain constant optical power. Any connection to the monitor pins should be high-impedance.

Enable/Disable

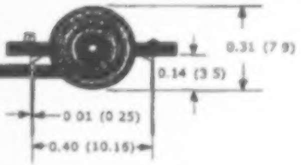
The disable function turns off the optical output. This feature may be used in applications where the output power must be off, such as when the transmitter is in standby mode.

Automatic Power Control

The automatic power control section maintains constant average power over the operating temperature range. The control also compensates for normal increases in the laser's operating current due to normal long-term aging effects.

User Connections

Typical connections that the user can implement to interface with ECL and PECL logic are indicated herein. Good high-frequency design techniques should be used when laying out a PC board to ensure good signal quality. A ground plane is recommended with the bypass capacitors and terminating resistors located as close to the module as possible.

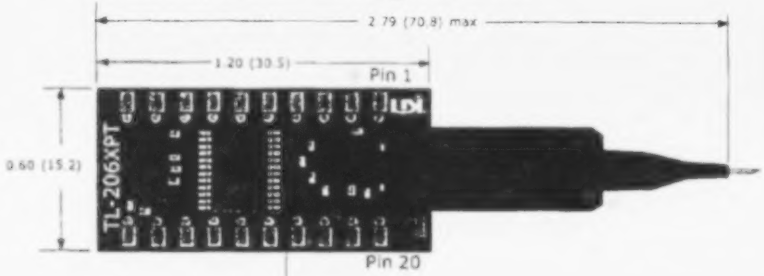


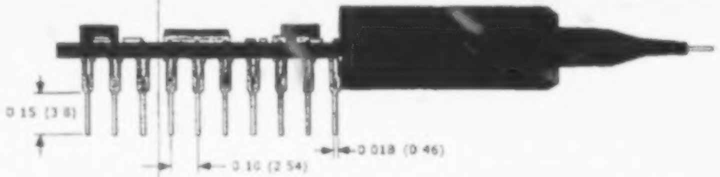
Pin Assignments

Pin	Function
1,3,10,20	no connection
2	laser bias monitor +
4	laser bias monitor -
5,14	V_{ee}
6,8,9,12,18	V_{cc}
7	disable
11,13	ground
15	data not
16	data
17	back facet monitor -
19	back facet monitor +

Airpaks use high quality surface mount assembly

Transmitter configuration





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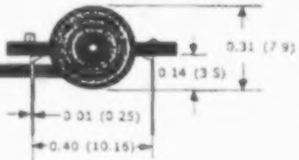

Pin Assignments

Pin	Function
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4	laser bias monitor -
5,14	V_{ee}
6,8,9,12,18	V_{cc}
7	disable
11,13	ground
15	data not
16	data
17	back facet monitor -
19	back facet monitor +

Airpaks use high quality surface mount assembly

Transmitter specifications and limits

Optical Characteristics		minimum	typical	maximum
Central wavelength	nm			
TL 2063, TL 2083		1290		1330
TL 2065, TL 2085		1520		1570
Average output power (over operating temperature range)	dBm			
TL 2063PT-010, TL 2065PT-010		-10	-8	-5
TL 2063PT-005		-5	-3	0
TL 2083PT-010, TL 2085PT-010		-10	-8	-5
TL 2083PT-005		-5	-3	0
Spectral width (RMS)	nm	-	2.5	-
Extinction ratio	dB	10	12	-
T_x disable[2]	V	-3.2	[illegible]	0

Electrical Characteristics				
Supply voltage (V_{cc}-V_{ee})	V	4.75	5	5.5
Supply current	mA	-	70	130
Input data voltage[2]	V			
Low		-	-1.8	-
High		-	-0.8	-
Bias monitor	V	0.01	[illegible]	0.45
Back facet monitor	V	0.01	[illegible]	0.2

Absolute Maximum Ratings				
Supply voltage	V	-		6
Storage temperature	°C	-40		85
Operating temperature[3]	°C	-40		85
Lead soldering temp/time	°C/secs	-		250/10

Notes.
[1] Performance is specified at 25°C
[2] Measured from V_{cc} with a 50-ohm load to V_{cc}-2 volts
[3] Temperature range for 1310 nm transmitters only

Application of Status Alarms

When implementing an external status alarm, a differential amplifier should be used to convert the differential monitor signal to a single-ended signal. This signal can then be fed to a simple comparator to detect a change in operating status. For example, the laser bias monitor can be used in conjunction with a differential amplifier and comparator to signal an increase in bias current of 50 percent or more at 25 °C indicating a possible malfunction

Evaluation Board

Test boards are available for simple interfacing to test equipment such as pattern generators. Contact the sales department for information.

Transmitter ordering information

Part Number	Typical Rate (NRZ Mb/s)	Nominal Wavelength (nm)	Typical P_{AVG} (dBm)	Interface Type	Operating Temperature (°C)
TL 2063PT-010FC	155	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2063PT-005FC	155	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2065PT-010FC	155	1550	-8	9/125 pigtail, FC/PC connector	0 to +65
TL 2083PT-010FC	622	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2083PT-005FC	622	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2085PT-010FC	622	1550	-8	9/125 pigtail, FC/PC connector	0 to +65

Note
1 FC/PC connectors on the fiber pigtail are standard Other connector types such as SC/PC are available through the sales department

Receiver sensitivity testing ensures performance integrity

Receivers

...continued on inside overleaf.

The Airpak 2000 Series receivers are high performance cost-effective optical modules optimized for use in SONET and SDH systems. The wide dynamic range transimpedance design accepts a maximum optical input power of 0 dBm while giving excellent sensitivity of -40 dBm at 52 Mb/s, -38 dBm at 155 Mb/s and -32 dBm at 622 Mb/s. A single +5 volt supply is required without the need for additional negative detector bias. However, to use the optical power-monitor function and to enhance sensitivity at 622 Mb/s, a negative voltage may be applied through Pin 10 of the module. Data outputs are differential PECL compatible. This highly compact receiver complies with an industry standard, 20-pin, dual-in-line footprint and has a multimode fiber pigtail, making it compatible with both singlemode and multimode systems.

Functional Description

Optical Front-end

The optical front-end consists of an InGaAs photodetector coupled to a wide dynamic range transimpedance amplifier for low noise and high bandwidth. An internal AGC circuit allows for input power up to 0 dBm.

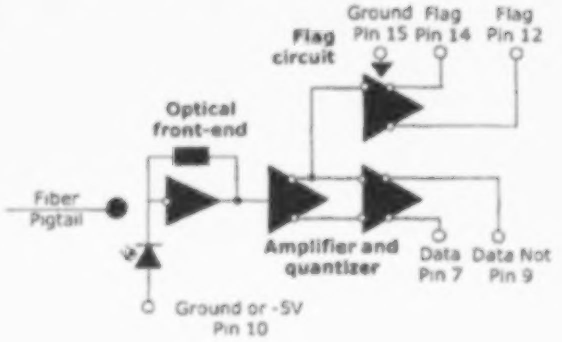
Amplifier and Quantizer

The amplifier stage has high gain and limits large-amplitude signals to maintain wide dynamic range

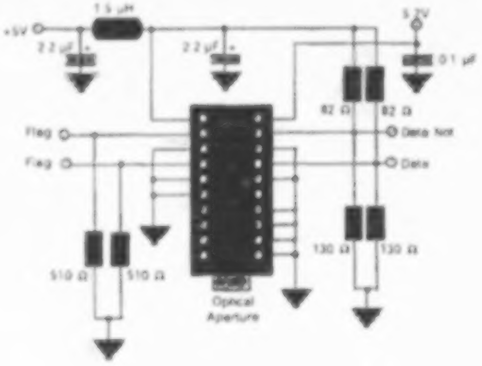
... continued on inside overleaf.

data rates of 52, 155, 622 Mb/s
1310 nm and 1550 nm operation
single 5-volt capable
high sensitivity
high overload power
wide dynamic range
differential data and flag outputs

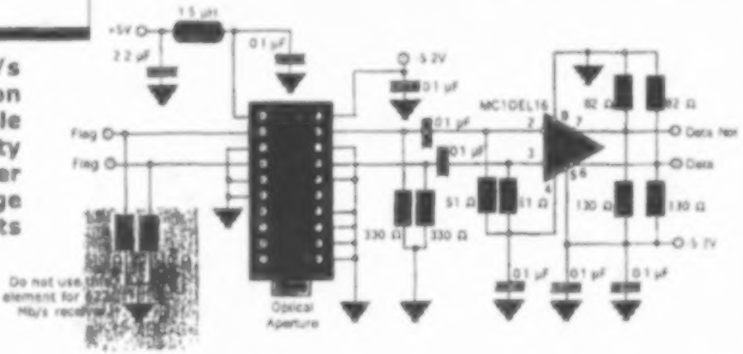
Receiver Functional Diagram


Ground Pin 15
Flag Pin 14
Flag Pin 12
Flag circuit
Optical front-end
Fiber Pigtail
Amplifier and quantizer
Data Pin 7
Data Not Pin 9
Ground or -5V Pin 10

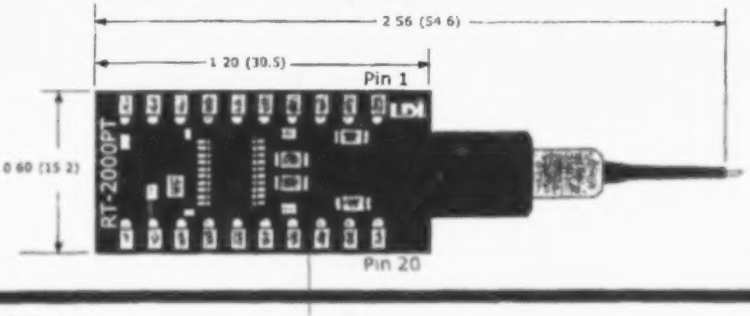
Recommended Receiver Bias for PECL Applications

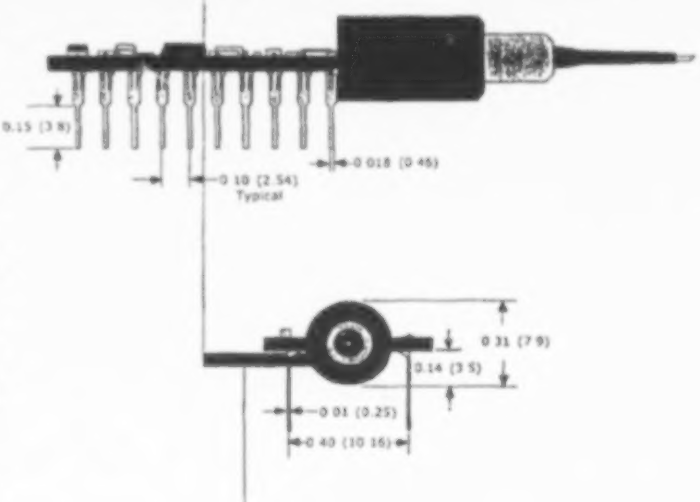

+5V
1.5 µH
2.2 µF
2.2 µF
5.2V
0.1 µF
82 Ω
82 Ω
Flag
Flag
Data Not
Data
510 Ω
510 Ω
130 Ω
130 Ω
Optical Aperture

Recommended Receiver Bias for ECL Applications


+5V
1.5 µH
2.2 µF
0.1 µF
5.2V
0.1 µF
MC10EL16
0.1 µF
0.1 µF
82 Ω
82 Ω
Flag
Flag
Data Not
Data
51 Ω
51 Ω
130 Ω
130 Ω
330 Ω
330 Ω
5.2V
0.1 µF
0.1 µF
0.1 µF
Optical Aperture
Do not use this element for 622 Mb/s receivers

Receiver configuration





The quantizer section provides PECL output levels to the data and flag outputs for 52 Mb/s and 155 Mb/s products. Data outputs are also PECL for the 622 Mb/s version, but the flags are TTL. This is compliant with the multisource standard.

Data Outputs

Data outputs are differential PECL (Positive or Pseudo-ECL). The recommended terminations are shown herein. It is recommended that differential outputs be used for connecting to other logic families to eliminate possible noise margin problems, particularly at elevated temperatures. Data outputs must be terminated in equivalent loads for optimal performance.

Flag Outputs

The flag circuit differentiates between the presence or absence of the optical signal with a minimum hysteresis of 1 dB. When an acceptable signal (see specification) is present, the flag output is logic high.

User Connections

Typical connections the user can implement to interface with ECL and PECL logic are indicated in accompanying schematics. Good high frequency design techniques should be used when laying out a PC board to ensure good signal quality. A ground plane is recommended, with the

Pin Assignments

Pin	Function
1,2,3,4,6	ground
8,13,15,16	ground
5,17,18,19,20	no connection
7	data
9	data not
10	-5 volt
11	+5 volt
12	flag+
14	flag-

Termination of fibers with a choice of optical connectors

Airpak transmitter and receiver modules ready for final performance testing.

bypass capacitors and terminating resistors located as close to the module as possible. Additional power supply filtering may be required if excessive noise is present due to nearby switching power supplies or other noise sources.

Power Supply

A +5 volt DC source is the only supply required. Pin 10 should be grounded if it is not used as a photodetector monitor. Pins 1, 2, 3, 4, and 16 may be left unconnected or may be grounded.

Photodetector Monitor

A photodetector monitor can be implemented for applications requiring access to a signal proportional to the input optical power. This option is implemented by connecting Pin 10 to the -5 volt supply through a series resistor. The signal is the voltage across the series resistor. It is recommended that the resistor have a maximum 2.7 Kohm value if the maximum optical input capability of the receiver is going to be used. If this function is not used, Pin 10 may be grounded.

Evaluation Board

An evaluation board is available to provide connections to test equipment such as oscilloscopes or BER testers. Contact Laser Diode's Sales Department for information.

Receiver specifications and limits

Optical Characteristics		minimum	typical	maximum
Measured average sensitivity[3]	dBm			
52 Mb/s		-38	[illegible]	-
155 Mb/s		-36	[illegible]	-
622 Mb/s		-30	[illegible]	-
Maximum input power	dBm	-3	0	-
Link status threshold	dBm			
(Flag-logic low)				
Decreasing light input				
52 Mb/s		-54	[illegible]	-38
155 Mb/s		-45	[illegible]	-36
622 Mb/s		-45	[illegible]	-28
Link status threshold	dBm			
(Flag-logic high)				
Increasing light input				
52 Mb/s		-55	[illegible]	-39
155 Mb/s		-44	[illegible]	-35
622 Mb/s		-44	[illegible]	-27
Electrical Characteristics				
Supply voltage (V_{CC})	V	4.8	5	5.3
Supply current	mA	-	100	150
Output data voltage[4]	V			
Low		-1.8	[illegible]	-1.5
High		-1.1	[illegible]	-
Output flag voltage[4]	[illegible]			
Low (52 Mb/s and 155 Mb/s)		-1.8	[illegible]	-1.5
High (52 Mb/s and 155 Mb/s)		-1.1	[illegible]	-
Low (622 Mb/s)[5]		-	[illegible]	0.5
High (622 Mb/s)[5]		3.0	[illegible]	-
Absolute Maximum Ratings				
Supply voltage	V	4.75	[illegible]	5.5
Operating case temperature	[illegible]	-40	[illegible]	85
Storage temperature	[illegible]	-40	[illegible]	85
Lead soldering temp/time	[illegible]	-	[illegible]	250/10

Notes

1 Performance is specified at 25°C

2 All values are at 1310 nm, BER 10^{-10}

3 Measured with an optical input using a 2^{23}-1 pseudo random pattern with a 50% duty cycle for a BER of 10^{-10}.

4 Measured from V_{CC} with a 50-ohm load to V_{CC}-2 volts

5 Measured from ground

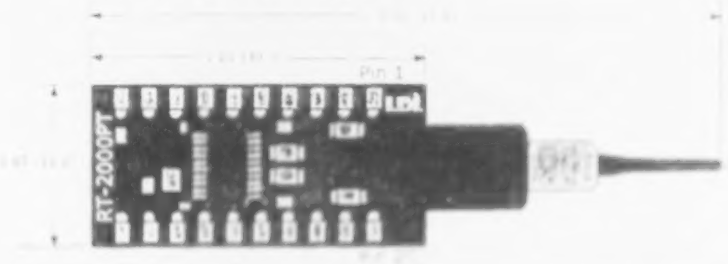
Receiver ordering information

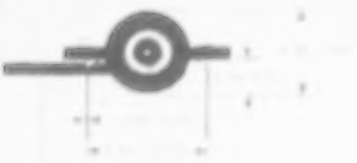
Part Number	Typical Rate (NRZ Mb/s)	Sensitivity (dBm)	Interface Type	Operating Temperature (°C)
RT 2000PT-052FC	52	-40	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-155FC	155	-38	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-622FC	622	-32	50/125 pigtail, FC/PC connector	-40 to +85

Note

FC/PC connectors on the fiber pigtail are standard. Other connector types such as SC/PC are available through the sales department.

Receiver configuration





The receiver section provides PECL output levels for the data and flag outputs for 50 Mb/s and 155 Mb/s products. Data outputs are also PECL for the 622 Mb/s version, but the flag are TTL. This is compatible with the [illegible].

Data Outputs

Data outputs are differential PECL. They are [illegible] Positive ECL. The recommended termination are shown [illegible]. It is recommended that differential outputs be used for connecting to other logic families to eliminate possible noise margin problems, particularly at elevated temperatures. Data outputs must be terminated in equivalent loads for optimum performance.

Flag Output

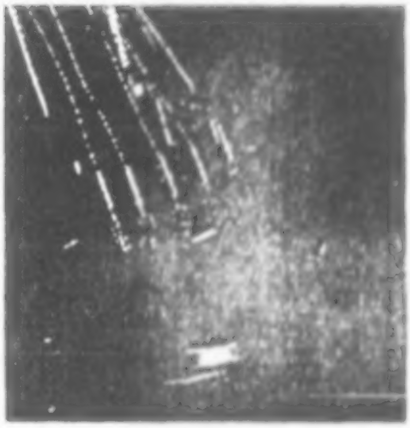
The flag output differential provides an indication of absence of the optical signal with a hysteresis typically of 1.5 dB. When no [illegible] signal [illegible] present, the flag output is a logic high.

Power Connections

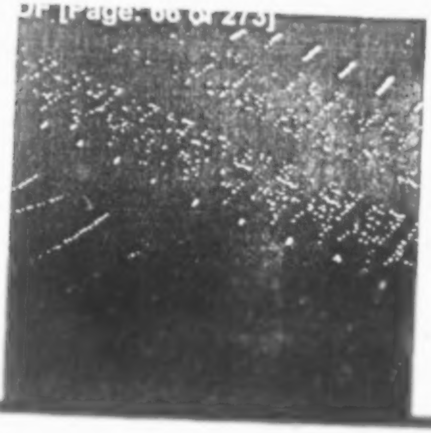
Power connections to the receiver are [illegible] with ECL and TTL [illegible] in [illegible]. Good high frequency design techniques should be used when laying out a PC board to ensure good power supply [illegible]. A ground plane is recommended with the

Pin Assignments

Pin	Function
1, 2, 3, 4, 5	ground
[illegible]	ground
[illegible]	no connection
[illegible]	Data
[illegible]	Data
[illegible]	−5 volt
[illegible]	+5 volt
[illegible]	Flag
[illegible]	Flag



[illegible]



A [illegible] motivates [illegible] performance [illegible]

bypass capacitors and [illegible] mounted as close to the [illegible] as possible. Additional power supply filtering may be required if excessive noise is present due to nearby switching power supplies or other components.

Power Supply

A +5 volt DC [illegible] is the only [illegible] [illegible] be provided [illegible] photodetector monitor [illegible] and [illegible] may be left [illegible] provided.

Photodetector Monitor

A photodetector monitor [illegible] for applications [illegible] to the [illegible] is implemented by [illegible] the 5 volt supply through a [illegible]. The signal is the voltage across the [illegible]. It is recommended that the [illegible] have a maximum of [illegible] value. [illegible] to be used [illegible] may be [illegible].

Evaluation Board

An evaluation board is available to [illegible] [illegible] to test a [illegible] such as [illegible] [illegible] contact your [illegible] department for information.

Receiver specifications and limits

Optical Characteristics

		Minimum	Typical	Maximum
Measured average sensitivity[1]				
52 Mb/s	[illegible]	-38	[illegible]	
155 Mb/s	[illegible]	-36	[illegible]	
622 Mb/s	[illegible]	-31	[illegible]	
Maximum input power	[illegible]	[illegible]	[illegible]	
Link status threshold				
(Flag logic low, Decreasing optical input)				
52 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]
155 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]
622 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]
Link status threshold				
(Flag logic high, Increasing optical input)				
52 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]
155 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]
622 Mb/s	[illegible]	[illegible]	[illegible]	[illegible]

Electrical Characteristics

		Minimum	Typical	Maximum
Supply voltage (V dc)	[illegible]	[illegible]	[illegible]	[illegible]
Supply current	[illegible]		[illegible]	[illegible]
Output data voltage[2]				
Low	[illegible]		[illegible]	
High	[illegible]	[illegible]	[illegible]	[illegible]
Output flag voltage[3]				
Low (52 Mb/s and 155 Mb/s)	[illegible]		[illegible]	
High (52 Mb/s and 155 Mb/s)	[illegible]	[illegible]	[illegible]	[illegible]
Low (622 Mb/s)	[illegible]	[illegible]	[illegible]	
High (622 Mb/s)	[illegible]	[illegible]	[illegible]	[illegible]

Absolute Maximum Ratings

		Minimum	Typical	Maximum
Supply voltage	[illegible]	[illegible]	[illegible]	[illegible]
Operating case temperature	[illegible]	-40	[illegible]	[illegible]
Storage temperature	[illegible]	-40	[illegible]	[illegible]
Lead soldering temp/time	[illegible]		[illegible]	[illegible]

Notes:
1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]

Receiver ordering information

Part Number	Data Rate (Mb/s)	Sensitivity (dBm)	Interface Type	Operating Temperature (°C)
[illegible]	52	[illegible]	50/125 pigtail, FC/PC connector	-40 to +85
[illegible]	155	[illegible]	50/125 pigtail, FC/PC connector	-40 to +85
[illegible]	622	[illegible]	50/125 pigtail, FC/PC connector	-40 to +85

Note:
[illegible]

Airpak
transmitter and receiver modules

Product changes
In seeking to provide greater value to our customers, Laser Diode, Inc. may make changes to its products that deviate from the information in this document.

Personal hazard
Normal aversion reactions will protect from radiation hazards to the eye associated with devices of this kind. Direct and prolonged exposure to a laser beam may cause eye damage. Observe precautions accompanying the product and precautions appropriate to a Class IIIb laser.

Handling precautions
Handle optical fiber with normal care, avoiding stretch, tension, twist, kink, or bend abuse. Products are subject to the risks normally associated with sensitive electronic devices including static discharge, transients, and overload.

Special orders
Some products can be supplied with performance characteristics that will meet special customer requirements and that are different from those indicated herein. Contact the Laser Diode Sales Department or your local Laser Diode representative to discuss your requirements.

Ordering
Products can be ordered directly from Laser Diode, Inc. or from its representatives. Refer to the following order numbers:

Transmitter ordering information

Part Number	Typical Rate (NRZ Mb/s)	Central Wavelength (nm)	Typical P_{AVG} (dBm)	Interface Type	Operating Temperature (°C)
TL 2063PT-010FC	155	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2063PT-005FC	155	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2065PT-010FC	155	1550	-8	9/125 pigtail, FC/PC connector	0 to +65
TL 2083PT-010FC	622	1310	-8	9/125 pigtail, FC/PC connector	-40 to +85
TL 2083PT-005FC	622	1310	-3	9/125 pigtail, FC/PC connector	-40 to +85
TL 2085PT-010FC	622	1550	-8	9/125 pigtail, FC/PC connector	0 to +65

Receiver ordering information

Part Number	Typical Rate (NRZ Mb/s)	Sensitivity (dBm)	Interface Type	Operating Temperature (°C)
RT 2000PT-052FC	52	-40	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-155FC	155	-38	50/125 pigtail, FC/PC connector	-40 to +85
RT 2000PT-622FC	622	-32	50/125 pigtail, FC/PC connector	-40 to +85

Note:
FC/PC connectors on the fiber pigtail are standard. Other connector types such as SC/PC are available through the sales department.

DANGER
INVISIBLE LASER RADIATION
AVOID DIRECT EXPOSURE TO BEAM
CLASS IIIb LASER PRODUCT

LDI

Laser Diode Incorporated
4 Olsen Avenue, Edison, New Jersey 08820 USA
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e-mail: sales@laserdiode.com

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Ruggedized
transmitter and receiver modules

- Rugged MIL-qualifiable data links
- Data rates to 125 Mb/s
- 1.3 µm LED operation
- 16-pin packages
- ECL, PECL data compatible
- FDDI, ARINC, SAFENET

Our series of ruggedized transmitters and receivers constitutes a complementary line of extended performance devices designed for implementation in extremely demanding environments. They are appropriate for commercial and military avionics systems, tactical military data communications, shipboard communications systems, or any fiber optic communication environment in which the normally less rugged device would be at risk. The transmitters and receivers use advanced hybrid technology to integrate a full-function device that delivers the demanding performance normally required of high-end data communications applications

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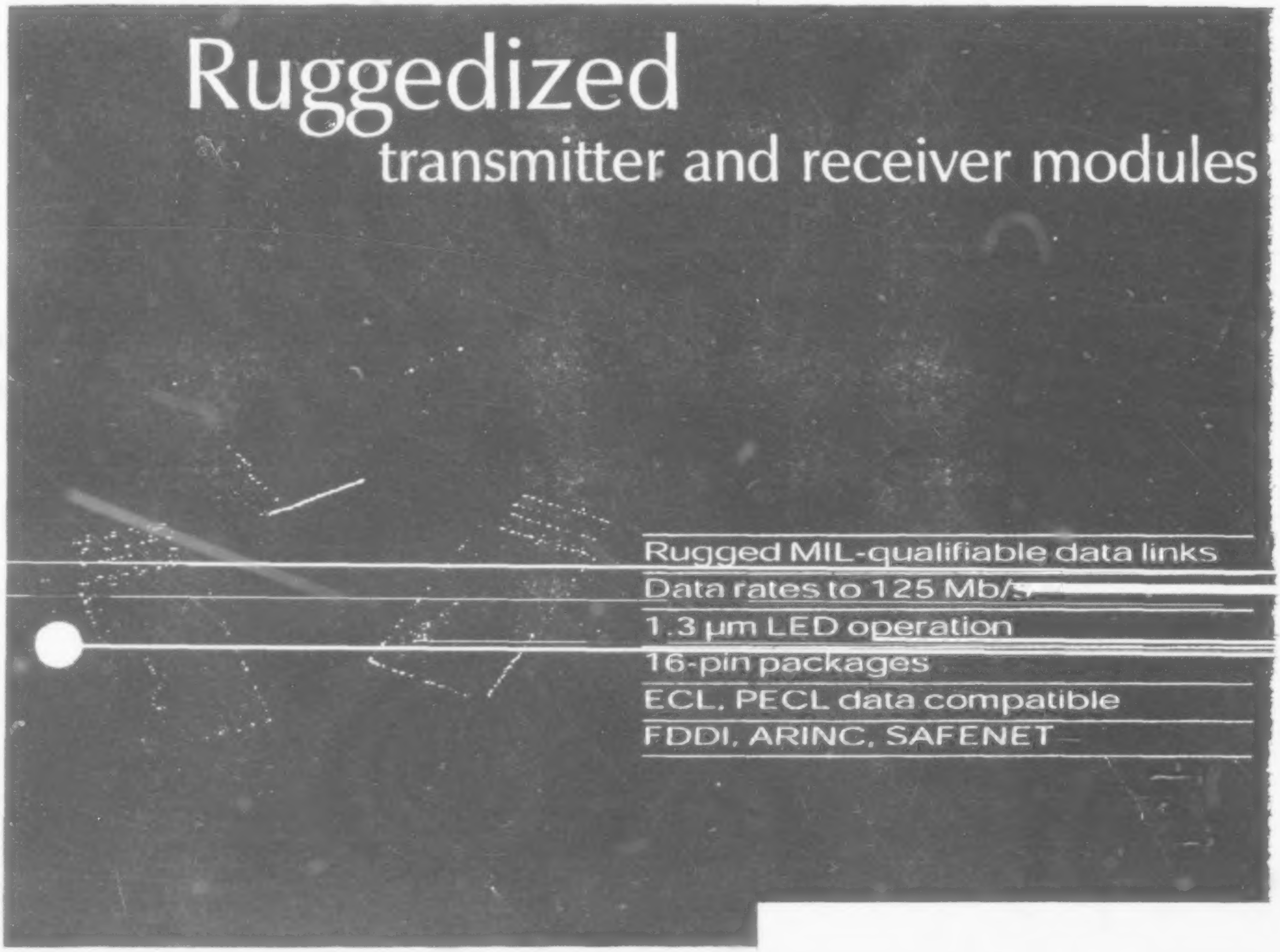
e-mail: sales@laserdiode.com



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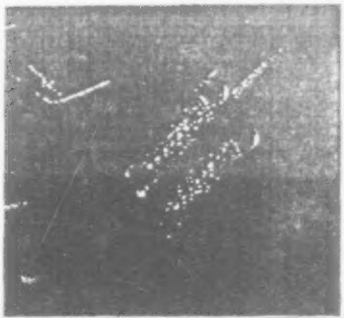


[illegible]

The TS-2143 transmitter incorporates a high reliability, surface emitting, light emitting diode (LED) packaged in a fiber pigtailed subassembly. This approach permits prescreening of the packaged LED component which ensures maximum reliability of a crucial element. Interface circuitry provides a 10 KH compatible differential PECL data input format along with a single +5 volt power supply for simple design integration.

The RT-2714 receiver incorporates a high reliability planar InGaAs PIN photodiode integrated into a fiber pigtailed subassembly with a low noise GaAs transimpedance preamplifier. This approach provides optimal sensitivity and wide dynamic range. The preamplifier is followed by gain stages and a comparator that provides a 10 KH PECL compatible output. The receiver operates on a single +5 volt power supply for ease of use. A low optical power alarm is provided that triggers a PECL output when the optical input drops below the minimum sensitivity.

The transmitter and receiver units are packaged in hermetically sealed 16-pin kovar packages with pinouts compatible with multisource FDDI modules. The optical output is a 62.5/125 µm pigtail terminated with a choice of optical connectors. A 50/125 or 100/140 fiber pigtail may also be accommodated if it better suits your application.

package diagrams
on inside next page

TS-2143 transmitter specifications and limits

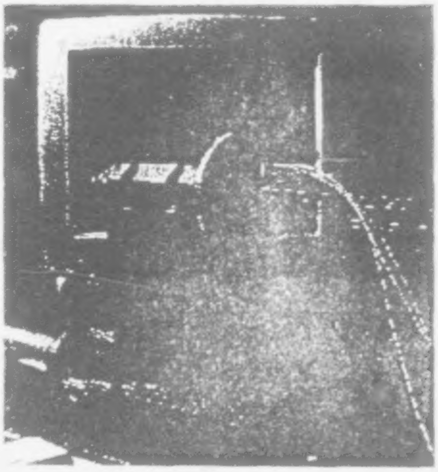
Optical Characteristics		minimum	maximum
Optical output power[1]	dBm	-16	
Rise/fall time	ns		2.5/3.5
Extinction ratio	%		10
Center wavelength	nm	1270	1380
Spectral width	nm		180
Electrical Characteristics			
NRZ data rate[3]	Mb/s	1	125
Data input voltage, low[4]	V	-1.81	-1.47
Data input voltage, high[4]	V	-1.16	-0.88
Power supply current (+5V)	mA		200
Operating case temperature	°C	-40	+85
Storage temperature	°C	-40	+85
Optical interface	1 meter 62.5/125 µm fiber pigtail		

Notes:
[illegible]

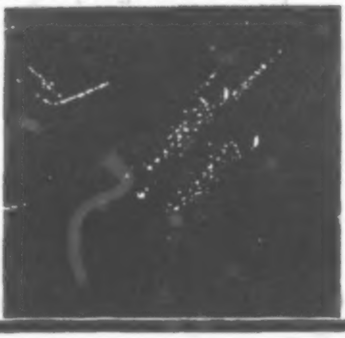
RT-2714 receiver specifications and limits

Optical Characteristics		minimum	typical	maximum
Sensitivity (at 125 Mb/s)[2]	dBm	-34	-36	
Overload power[3]	dBm	-9	-3	
Alarm assert	dBm	-43	-41	-34
Alarm deassert	dBm	-44		-35
Rise/fall time	ns			3.0
Electrical Characteristics				
NRZ data rate[4]	Mb/s	10		125
Data output voltage, low	V	-1.81		-1.47
Data output voltage, high	V	-1.16		-0.88
Power supply current (+5V)	mA		150	200
Operating case temperature	°C	-40		+85
Storage temperature	°C	-40		+85
Optical interface	1 meter 62.5/125 µm fiber pigtail			

Notes:
[illegible]



[illegible]



Ruggedized data links incorporate ceramic pin-seals to optimize hermeticity

The TS-2143 transmitter incorporates a high reliability, surface emitting, light emitting diode (LED) packaged in a fiber pigtailed subassembly. This approach permits pre-screening of the packaged LED component which ensures maximum reliability of a crucial element. Interface circuitry provides a 10 KH compatible differential PECL data input format along with a single +5 volt power supply for simple design integration.

The RT-2714 receiver incorporates a high reliability planar InGaAs PIN photodiode integrated into a fiber pigtailed subassembly with a low noise GaAs transimpedance preamplifier. This approach provides optimal sensitivity and wide dynamic range. The preamplifier is followed by gain stages and a comparator that provides a 10 KH PECL compatible output. The receiver operates on a single +5 volt power supply for ease of use. A low optical power alarm is provided that triggers a PECL output when the optical input drops below the minimum sensitivity.

The transmitter and receiver units are packaged in hermetically sealed 16-pin kovar packages with pinouts compatible with multisource FDDI modules. The optical output is a 62.5/125 µm pigtail terminated with a choice of optical connectors. A 50/125 or 100/140 fiber pigtail may also be accommodated if it better suits your application.

...package diagrams on inside next page.

TS-2143 transmitter specifications and limits

Optical Characteristics		minimum	maximum
Optical output power[1]	dBm	-16	-
Rise/fall time	ns	-	2.5/2.5
Extinction ratio	%	-	10
Center wavelength	nm	1270	1380
Spectral width	nm	-	180
Electrical Characteristics			
NRZ data rate[3]	Mb/s	1	125
Data input voltage, low[4]	V	-1.81	-1.47
Data input voltage, high[4]	V	-1.16	-0.88
Power supply current (+5V)	mA	-	200
Operating case temperature	°C	-40	+85
Storage temperature	°C	-40	+85
Optical interface	1 meter 62.5/125 µm fiber pigtail		

Notes

1. Performance is specified for a temperature range of -40°C to +85°C
2. Average output power is based on a 50% duty cycle
3. Consult with Laser Diode sales department for operation below 1 Mb/s
4. Measured from V_{CC} with a 50 ohm load to -2 volts

RT-2714 receiver specifications and limits

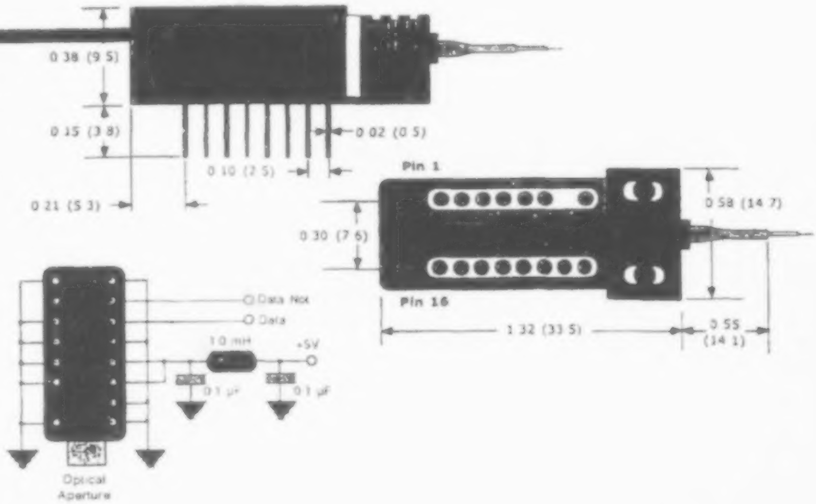
Optical Characteristics		minimum	typical	maximum
Sensitivity (at 125 Mb/s)[2]	dBm	-34	-36	-
Overload power[3]	dBm	-6	[illegible]	-
Alarm assert	dBm	-43		-34
Alarm deassert	dBm	-44		-35
Rise/fall time	ns	-		3.0
Electrical Characteristics				
NRZ data rate[4]	Mb/s	10		125
Data output voltage, low[5]	V	-1.81		-1.47
Data output voltage, high[5]	V	-1.16		-0.88
Power supply current (+5V)	mA	-	150	200
Operating case temperature	°C	-40		+85
Storage temperature	°C	-40		+85
Optical interface	1 meter 62.5/125 µm fiber pigtail.			

Notes

1. Performance is specified for a temperature range of -40°C to +85°C
2. Minimum average optical power required to maintain a BER=10^{-9}. The -052 option will support data rates up to 52 Mb/s. The -125 option will support data rates up to 125 Mb/s or to 160 Mb/s with screening. Consult the Laser Diode sales department
3. Maximum average optical input to maintain a BER=10^{-9}
4. Receivers with higher data rates are available
5. Measured from V_{CC} with a 50 ohm load to -2 volts

Precision fiber polishing optimizes optical coupling

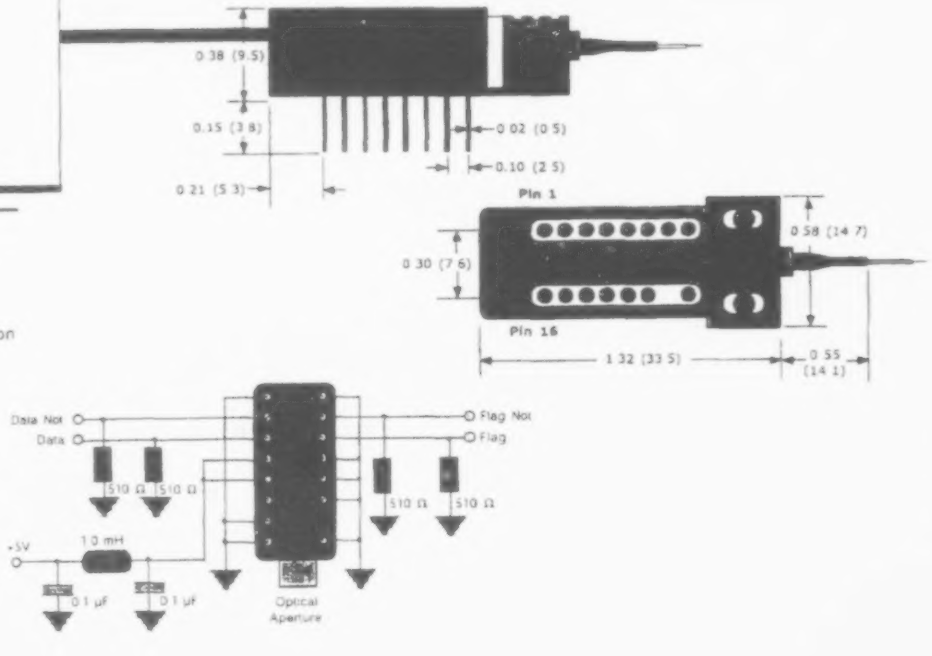
TS-2143 Transmitter Package


0.38 (9.5)
0.15 (3.8)
0.02 (0.5)
0.10 (2.5)
0.21 (5.3)
Pin 1
0.58 (14.7)
0.30 (7.6)
Pin 16
1.32 (33.5)
0.55 (14.1)
Data Not
Data
1.0 mH
+5V
0.1 µF
0.1 µF
Optical Aperture

Pin Assignments

Pin	Function
1,3,4,8,9	ground
10,13,16	ground
2	no connection
5,6	ground
7	no pin
11,12	V_{CC}
14	data
15	data not

RT-2714 Receiver Package


0.38 (9.5)
0.15 (3.8)
0.02 (0.5)
0.10 (2.5)
0.21 (5.3)
Pin 1
0.58 (14.7)
0.30 (7.6)
Pin 16
1.32 (33.5)
0.55 (14.1)
Data Not
Data
510 Ω
510 Ω
Flag Not
Flag
510 Ω
510 Ω
+5V
1.0 mH
0.1 µF
0.1 µF
Optical Aperture

Pin Assignments

Pin	Function
1,7,8,9,11	ground
12,13,16	ground
2	data not
3	data
4	V_{CC}
5	V_{CC}
6	no connection
10	no pin
14	flag
15	flag not

The TS-1158 (850 nm) and TS-1153 (1300 nm) transmitter modules use high-reliability surface-emitting LED (SLED) technology at their respective wavelengths. The optical elements in these transmitter assemblies are packaged in active-device receptacles in either the ST® or SMA format. This allows a simple connection interface to the optical fiber.

The module electrical interface is standard ECL-compatible and the package is a hermetic, 16-pin, gold plated kovar module with ceramic pin feedthroughs.

The RP-1152 (850 nm) and RP-1154 (1300 nm) receiver assemblies incorporate low-capacitance, high-responsivity silicon or InGaAs PIN diodes. These devices are assembled into active-device receptacles in the ST® or SMA formats to be compatible with the matching transmitter products. The current from the PIN diode is converted to an ECL digital signal by a transimpedance amplifier, a filter stage, and a quantizer. The module housing is also a hermetic, 16-pin, gold plated kovar module with ceramic pin feedthroughs.

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TS-1150 series transmitter specifications and limits

		850 nm TS-1158			1300 nm TS-1153		
Optical Characteristics		min	typ	max	min	typ	max
Rise/fall time[1]	ns	-	4	6	-	3	4
Overshoot	%	-	5	15	-	5	15
Pulse width distortion	ns	-	[illegible]	-	-	1	-
Optical output, average	μW(dBm)						
50 μm fiber		-	12.5(-19)	-	-	10(-20)	-
62.5 μm fiber		-	25(-16)	-		20(-17)	-
100 μm fiber		-	50(-13)	-	-	40(-14)	-
Extinction ratio	%	5	[illegible]	-	5	[illegible]	-
Electrical Characteristics							
NRZ data rate	Mb/s	1		100	1		125
Input voltage, high	V	-1.31		-0.81	-1.31		-.81
Input voltage, low	V	-1.95		-1.48	-1.95		-1.48
Power supply (-5.2 +/-0.5) volts	mA	-	160	200	-	160	200
Operating case temperature	°C	-40		+85	-40		+85
Storage temperature	°C	-40		+85	-40		+85

Notes:
1. Performance is specified for a temperature of 25°C
2. 10% to 90% with no pre-bias

RP-1150 series receiver specifications and limits

		850 nm RP-1152			1300 nm RP-1154		
Optical Characteristics		min	typ	max	min	typ	max
Sensitivity	dBm	-30	-32	-	-32	-34	-
Dynamic range	dB	18	20	-	18	20	-
Optical loss budget[3]	dB	-	16	-	-	17	-
Electrical Characteristics							
NRZ data rate[4]	Mb/s	1		100	1		125
Output voltage, high	V	-0.98		-0.81	-0.98		0.81
Output voltage, low	V	-1.95		-1.63	-1.95		-1.63
Power supply[5] (-5.2 +/-0.5) volts	mA	-	110	125	-	110	125
Operating case temperature	°C	-40		+85	-40		+85
Storage temperature	°C	-40		+85	-40		+85

Notes:
1. Performance is specified for a temperature of 25°C
2. Receiver provides low-light-level alarm
3. For 62.5 μm fiber when used with TS-1150 series transmitters.
4. PRBS (2[illegible]) -1 at 1 Mb/s, (2[illegible]) -1 at 100 Mb/s
5. +5 volt operation available on request

Receiver sensitivity testing ensures performance integrity.

TS-1150 series transmitter specifications and limits

		850 nm TS-1158			1300 nm TS-1153		
Optical Characteristics		min	typ	max	min	typ	max
Rise/fall time[2]	ns	-	4	6	-	3	4
Overshoot	[illegible]	-	[illegible]	15	-	5	15
Pulse width distortion	ns	-	[illegible]	-	-	1	-
Optical output, average	µW(dBm)						
50 µm fiber		-	12.5(-19)	-	-	10(-20)	-
62.5 µm fiber		-	25(-16)	-	-	20(-17)	-
100 µm fiber		-	50(-13)	-	-	40(-14)	-
Extinction ratio	[illegible]	5	[illegible]	-	5	[illegible]	-
Electrical Characteristics							
NRZ data rate	Mb/s	1	[illegible]	100	1	[illegible]	125
Input voltage, high	V	-1.31	[illegible]	-0.81	-1.31	[illegible]	-.81
Input voltage, low	V	-1.95	[illegible]	-1.48	-1.95	[illegible]	-1.48
Power supply (-5.2 +/-0.5) volts	[illegible]	-	160	200	-	160	200
Operating case temperature	[illegible]	-40	[illegible]	+85	-40	[illegible]	+85
Storage temperature	[illegible]	-40	[illegible]	+85	-40	[illegible]	+85

Notes:
[1] Performance is specified for a temperature of 25°C
[2] 10% to 90% with no pre-bias

The TS-1158 (850 nm) and TS-1153 (1300 nm) transmitter modules use high-reliability surface-emitting LED (SLED) technology at their respective wavelengths. The optical elements in these transmitter assemblies are packaged in active-device receptacles in either the ST® or SMA format. This allows a simple connection interface to the optical fiber.

The module electrical interface is standard ECL-compatible and the package is a hermetic, 16-pin, gold plated kovar module with ceramic pin feedthroughs.

The RP-1152 (850 nm) and RP-1154 (1300 nm) receiver assemblies incorporate low-capacitance, high-responsivity silicon or InGaAs PIN diodes. These devices are assembled into active-device receptacles in the ST® or SMA formats to be compatible with the matching transmitter products. The current from the PIN diode is converted to an ECL digital signal by a transimpedance amplifier, a filter stage, and a quantizer. The module housing is also a hermetic, 16-pin, gold plated kovar module with ceramic pin feedthroughs.

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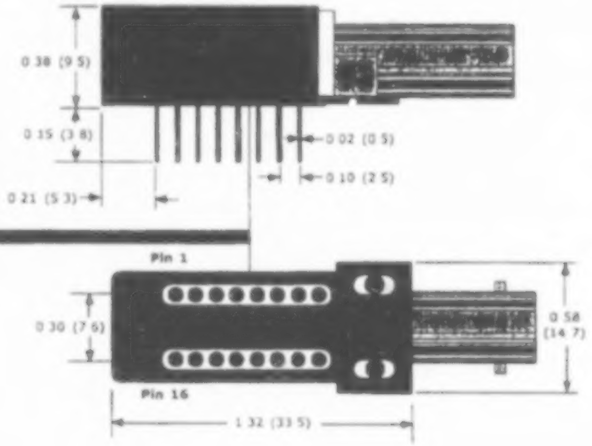
RP-1150 series receiver specifications and limits

		850 nm RP-1152			1300 nm RP-1154		
Optical Characteristics		min	typ	max	min	typ	max
Sensitivity	dBm	-30	-32	-	-32	-34	-
Dynamic range	dB	18	20	-	18	20	-
Optical loss budget[3]	dB	-	16	-	-	17	-
Electrical Characteristics							
NRZ data rate[4]	Mb/s	1	[illegible]	100	1	[illegible]	125
Output voltage, high	V	-0.98	[illegible]	-0.81	-0.98	[illegible]	-0.81
Output voltage, low	V	-1.95	[illegible]	-1.63	-1.95	[illegible]	-1.63
Power supply[5] (-5.2 +/-0.5) volts	mA	-	110	125	-	110	125
Operating case temperature	°C	-40	[illegible]	+85	-40	[illegible]	+85
Storage temperature	°C	-40	[illegible]	+85	-40	[illegible]	+85

Notes:
[1] Performance is specified for a temperature of 25°C
[2] Receiver provides low-light-level alarm
[3] For 62.5 µm fiber when used with TS-1150 series transmitters.
[4] PRBS: $(2^7)-1$ at 1 Mb/s, $(2^{23})-1$ at 100 Mb/s
[5] +5 volt operation available on request

Receiver sensitivity testing ensures performance integrity

TS/RP-1150 Transmitter and Receiver Packages


0.38 (9.5)
0.15 (3.8)
0.02 (0.5)
0.10 (2.5)
0.21 (5.3)
Pin 1
0.30 (7.6)
0.58 (14.7)
Pin 16
1.32 (33.5)

continued from overleaf.

The links interface to standard differential ECL data signals and are powered from a single -5.2V supply (+5V also available). These links are housed in hermetically sealed 16-pin DIL packages. The standard modules operate over a -40 to +85°C temperature range. These data links were specifically developed to be qualifiable to MIL-STD 883, Method 5008, Class B. Units screened to 883 and wider temperature ranges are available upon request.

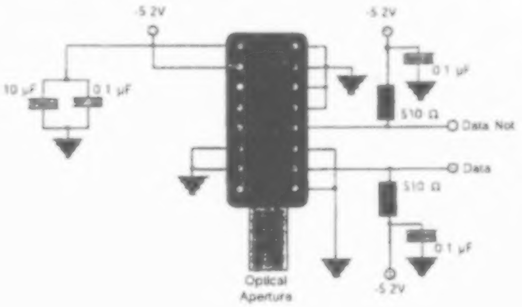
Transmitter Pin Assignments

Pin	Function
1,2	V_{ee}
3,4,5	no connection
6,7,11	ground
8	V_{bb}
9,13,14,15,16	ground
10	data
12	data not

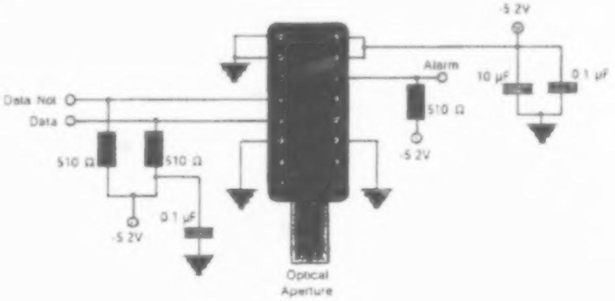
Receiver Pin Assignments

Pin	Function
1,2	ground
3,7,8,9,10,12,13	no connection
4	data not
5	data
6,11	ground
14	alarm
15,16	V_{ee}

Recommended ECL transmitter termination with short interconnections (TS-1150 series)


-5.2V
-5.2V
10 µF
0.1 µF
0.1 µF
510 Ω
Data Not
Data
510 Ω
0.1 µF
Optical Aperture
-5.2V

Recommended ECL receiver termination with short interconnections (RP-1150 series)


-5.2V
Alarm
10 µF
0.1 µF
Data Not
Data
510 Ω
510 Ω
510 Ω
-5.2V
-5.2V
0.1 µF
Optical Aperture

Ruggedized Transmitter and Receiver Modules

Product changes
In seeking to provide greater value to our customers, Laser Diode, Inc. may make changes to its products that deviate from the information in this document.

Personal hazard
Normal aversion reactions will protect from radiation hazards to the eye associated with devices of this kind. Direct and prolonged exposure to a laser beam may cause eye damage. Observe precautions accompanying the product and precautions appropriate to a Class IIIb laser.

Handling precautions
Handle optical fiber with normal care, avoiding stretch, tension, twist, kink, or bend abuse. Products are subject to the risks normally associated with sensitive electronic devices including static discharge, transients, and overload.

Special orders
Some products can be supplied with performance characteristics that will meet special customer requirements and that are different from those indicated herein. Contact the Laser Diode Sales Department or your local Laser Diode representative to discuss your requirements.

Ordering
Products can be ordered directly from Laser Diode, Inc. or from its representatives. Refer to the following order numbers:

Order numbers

Part number	Description
TS-2143-016	Transmitter, 1300 nm, PECL, 125 Mb/s, -16 dBm, 62.5/125 pigtail
RT-2714-052	Receiver, PECL, 52 Mb/s, 52.5/125 pigtail
RT-2714-125	Receiver, PECL, 125 Mb/s, 62.5/125 pigtail
TS-1158ST-016	Transmitter, 850 nm, ECL, 100 Mb/s, -16 dBm, ST® receptacle
TS-1153ST-017	Transmitter, 1300 nm, ECL, 100 Mb/s, -17 dBm, ST® receptacle
RP-1152ST-100	Receiver, 850 nm, ECL, 100 Mb/s, -32 dBm, ST® receptacle
RP-1154ST-100	Receiver, 1300 nm, ECL, 100 Mb/s, -34 dBm, ST® receptacle

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Qualification capabilities to MIL-STD-883

Solderability	Method 2003
Lead integrity	Method 2004-B2
Resistance to solvents	Method 2015
Internal visual inspection	Method 2014
Wirebond strength	Method 2011-D
Die shear strength	Method 2019
Physical dimensions	Method 2016
Hermeticity, gross	Method 1014-C1
Hermeticity, fine	Method 1014-A1
Thermal shock	Method 1010-A
Steady-state life	Method 1005-B
Mechanical shock	Method 2002
Constant acceleration	Method 2001

Note
The ruggedized devices described in this document are designed to be used in environments that are too demanding for a standard commercial-grade device. Extensive individual qualification has been conducted to ensure the long-term integrity and performance of these products. An example of a possible qualification plan is given here for the convenience and information of our customers. Though the devices have been rigorously tested for demanding conditions typical of those encountered in the field, it is not suggested that all devices have been tested in all conditions or will pass all tests indicated in the accompanying plan.

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Voice: 732-549-9001, Fax: 732-906-1559
Internet: www.laserdiode.com
e-mail: sales@laserdiode.com

Data Sheet
September 1999

microelectronics group

Lucent Technologies
Bell Labs Innovations

1241/1243/1245-Type Uncooled Laser Transmitter

Lucent
Tx
X1243 155MB
7390854

Offering multiple output power options and SONET/SDH compatibility, the 1241/1243-Type Uncooled Laser Transmitter is manufactured in a 20-pin, plastic DIP with a single-mode fiber pigtail.

Features

- Backward compatible with 1227/1229/1238-Type Laser Transmitters
- Space-saving, self-contained, 20-pin DIP
- Uses field-proven, reliable InGaAsP MQW laser
- Requires single 5 V power supply
- SONET/SDH compatible
- Uncooled laser with automatic optical power control for constant output power over case temperature range
- No thermoelectric cooler required; reduces size and power consumption
- Uses low-power dissipation CMOS technology
- Qualified to meet the intent of Bellcore reliability practices
- Operates over data rates to 1062.5 Mbits/s (NRZ)
- Operation at 1.3 µm or 1.55 µm wavelength
- Typical average output power options of –11 dBm, –8 dBm, –5 dBm, –2 dBm, and 0 dBm
- ECL compatible, differential inputs
- Operating temperature range of –40 °C to +85 °C
- Transmitter-disable option

Applications

- Telecommunications
  - — Inter- and intraoffice SONET/ITU-T SDH
  - — Subscriber loop
  - — Metropolitan area networks
- High-speed data communications
  - — Fibre channel (FC-0)

Description

The 1241/1243/1245-type Laser Transmitters are designed for use in transmission systems and high-speed data communication applications. Used in intraoffice and intermediate-reach applications, the transmitters are configured to operate at SONET rates up to OC-12, as well as at ITU-T synchronous digital hierarchy (SDH) rates up to STM-4. Specific versions are also capable of operating up to 1062.5 Mbits/s.

The transmitter meets all present Bellcore GR-253-CORE requirements, ANSI T1.117-1991 SONET single-mode, and the ITU-T G.957 and G.958 recommendations. (See Table 5 to select transmitters for the various SONET/SDH segments.)

The transmitter requires a single power supply (+5 V or –5 V) and operates over data rates of 1 Mbits/s to 622 Mbits/s (NRZ). Automatic power control circuitry provides constant optical output power over the operating case temperature range. The automatic power control circuitry also compensates for laser aging. The optical wavelength tolerance at 25 °C is 1310 nm. The temperature coefficient of wavelength for 1.3 µm Fabry-Perot transmitters (1241-Type) is approximately 0.4 nm/°C. The temperature coefficient of wavelength for 1.3 µm and 1.55 µm distributed-feedback (DFB) transmitters (1243/1245-Type) is approximately 0.1 nm/°C.

Transmitters are available for operation over several different temperature ranges from –40 °C to +85 °C. Manufactured in a 20-pin DIP, the transmitter consists of a hermetic, InGaAs laser and a single CMOS driver IC. The low-power consumption circuit provides modulation, automatic optical output power control, and data reference. The module can be driven by either ac- or dc-coupled data in single-ended or differential configuration. (See Recommended User Interfaces section for typical connection schemes.) The laser bias and back-facet monitor currents are electrically accessible for transmitter performance monitoring. The transmitter optical output may be disabled by a logic-level input.

Functional Overview

Transmitter Circuit Description and Operation

Figure 1 shows a simplified schematic of the transmitter; pin information is listed in Table 1. The laser within the transmitter is driven by a single CMOS integrated circuit, which provides the input data signal reference level with automatic, temperature-compensated laser bias, and modulation-current control. A back-facet photodetector diode within the laser module provides an indication of the laser's average optical output power. The back-facet diode current is accessible as a voltage proportional to photocurrent through pins 17 and 19 on the transmitter. The back-facet diode also forms part of the feedback control circuit, which helps maintain constant output power.

The laser bias current is accessible as a dc-voltage by measuring the voltage developed across pins 2 and 4 of the transmitter. Dividing this voltage by 10 Ω will yield the value of the laser bias current. This value will change up or down in response to operating temperature, power supply voltage, data pattern, and laser aging characteristics.

Table 1. Pin Descriptions

Pin Number	Name
1	No user connection[*]
2	Laser bias monitor (+)[†]
3	No user connection[*]
4	Laser bias monitor (–)[†]
5	V_{EE}
6	V_{CC}
7	Transmitter disable
8	V_{CC}
9	V_{CC}
10	No user connection[†]
11	Case ground (RF ground)
12	V_{CC}
13	Case ground (RF ground)
14	V_{EE}
15	$\overline{\text{DATA}}$
16	DATA
17	Laser back-facet monitor (–)[*]
18	V_{CC}
19	Laser back-facet monitor (+)[*]
20	No user connection[†]

[*] Pins designated as no user connection should not be tied to ground or any other circuit potential.

[†] Laser back-facet and bias monitor functions are customer-use options that are not required for normal operations of the transmitter. They are normally used during manufacture and for diagnostics.

[illegible] PDF [Page: 76 of 273]

Functional Overview (continued)

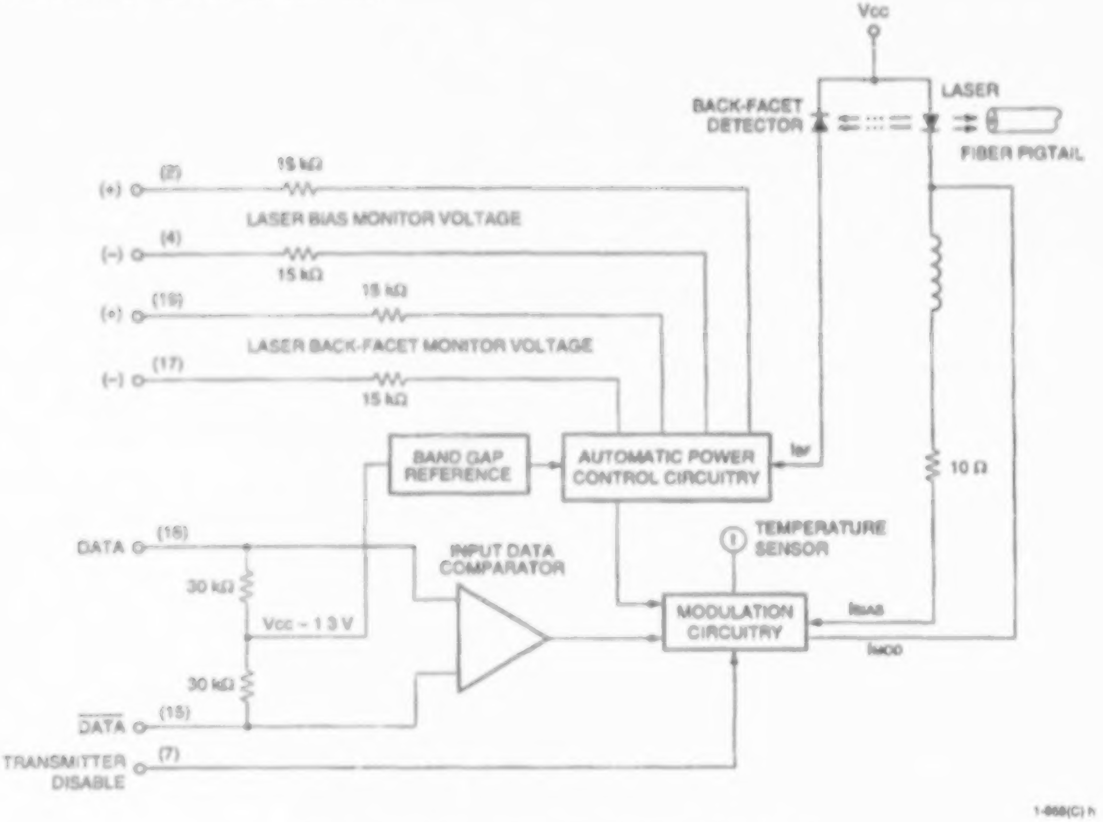

Vcc
BACK-FACET DETECTOR
LASER
FIBER PIGTAIL
(+)
(2)
15 kΩ
LASER BIAS MONITOR VOLTAGE
(−)
(4)
15 kΩ
(+)
(16)
15 kΩ
LASER BACK-FACET MONITOR VOLTAGE
(−)
(17)
15 kΩ
BAND GAP REFERENCE
AUTOMATIC POWER CONTROL CIRCUITRY
I_{BF}
10 Ω
TEMPERATURE SENSOR
DATA
(18)
30 kΩ
INPUT DATA COMPARATOR
MODULATION CIRCUITRY
I_{BIAS}
I_{MOD}
Vcc − 1.3 V
30 kΩ
$\overline{\text{DATA}}$
(15)
TRANSMITTER DISABLE
(7)
1-868(C) h

Figure 1. Simplified Transmitter Schematic Input Data

Input Data

Data enters the transmitter through a comparator. These inputs have internal pull-down resistors to a voltage reference that is 1.3 V below Vcc. This configuration allows the transmitter to be driven from either a single-ended or a differential input signal. Since the input is a comparator instead of a gate, the absolute input signal levels are not important when the inputs are driven differentially. When driven single-ended, however, the input signal voltage should be centered around Vcc − 1.3 V to eliminate pulse-width distortion. With a single-ended input, either input can be used and the unused input can be left as an open circuit due to the internal reference shown in Figure 1. The optical output signal will be in the same sense as the input data—an input logic high turns the laser diode on and an input logic low turns the laser diode off. However, if the negative input is used with a single-ended data input signal, the optical signal will be the complement of the data input signal.

The differental inputs of the 1241 Gbit versions are terminated internally with 100 Ω between the DATA and $\overline{\text{DATA}}$ inputs.

Minimum Data Rate

Because the modulation and bias control circuitry are influenced by the input data pattern, the standard transmitter cannot be used in burst-mode type applications. For burst-mode applications, please contact your Lucent Account Manager. The minimum data rate (pseudorandom data, 50% average duty cycle) for the 1241/1243/1245-Type Transmitters is approximately 1 Mbit/s.

Functional Overview (continued)

Since most applications operate at very high data rates, high-frequency design techniques need to be used to ensure optimum performance from the transmitter and interfacing circuitry. Input signal paths should be kept as short and as straight as possible; differential signal lines should be equal in length, and controlled-impedance stripline or microstrip construction should always be used when laying out the printed-wiring board traces for the data lines. The Recommended User Interfaces section of this data sheet shows several methods of interfacing to the transmitter.

Power Supplies

The transmitter is configured for operation from either a single +5 V power supply or a single –5 V power supply. For positive power supply operation, connect Vcc to the +5 V power supply and connect VEE to ground or circuit common. For operation from a –5 V power supply, connect Vcc to ground and connect VEE to the –5 V power supply. Whichever option is chosen, the Vcc or VEE connection to the transmitter should be well filtered to prevent power supply noise from interfering with transmitter operation.

Transmitter Specifications

Optical Output Power

During manufacture, the optical output power of every transmitter is tuned to the typical value specified in the data sheet for that particular transmitter code. The tuning is performed at room ambient and a power supply voltage of 5 V. The minimum and maximum values listed in the data sheet for each code group reflect the worst-case limits that the transmitter is expected to operate within over its lifetime and over the allowed power supply and the operating temperature range.

Every transmitter shipped receives a final test, which includes a SONET eye-mask test at either the OC-3 (STM-1) data rate of 155.52 Mbits/s, the OC-12 (STM4) data rate of 622.08 Mbits/s, or the fibre channel FC-0 data rate of 1062.5 Mbits/s. The eye-mask test is meant to examine the performance of the transmitter's output optical waveform relative to a minimum data pattern eye opening.

Connector Options

The standard optical fiber pigtail is 8 μm core single-mode fiber having a 0.036 in. (914 μm) diameter tight-buffered outer-jacket. The standard length is 39 in. ± 4 in. (1 m ± 10 cm) and can be terminated with either an SC or FC-PC optical connector. Other connector options may be available on special order. Contact your Lucent Account Manager for ordering information.

Handling Precautions

CAUTION: This device is susceptible to damage as a result of electrostatic discharge (ESD). Take proper precautions during both handling and testing. Follow guidelines such as JEDEC Publication No. 108-A (Dec. 1988).

Although protection circuitry is designed into the device, take proper precautions to avoid exposure to ESD. Lucent employs a human-body model (HBM) for ESD-susceptibility testing and protection-design evaluation. ESD voltage thresholds are dependent on the critical parameters used to define the model. A standard HBM (resistance = 1.5 kΩ, capacitance = 100 pF) is widely used and, therefore, can be used for comparison purposes. The HBM ESD withstand voltage established for the 1241-/1243-Type Transmitter is ±1000 V.

Transmitter Processing

The transmitter can withstand normal wave-soldering processes. The complete transmitter module is not hermetically sealed; therefore, it should not be immersed in or sprayed with any cleaning solution or solvents. The process cap and fiber pigtail jacket deformation temperature is 85 °C. Transmitter pins can be wave-soldered at maximum temperature of 250 °C for 10 seconds.

Installation Considerations

Although the transmitter features a robust design, care should be used during handling. The optical connector should be kept free from dust, and the process cap should be kept in place as a dust cover when the device is not connected to a cable. If contamination is present on the optical connector, canned air with an extension tube can be used to remove any debris. Other cleaning procedures are identified in the technical note, *Cleaning Fiber-Optic Assemblies* (TN95-010LWP).

Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are absolute stress ratings only. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of the data sheet. Exposure to absolute maximum ratings for extended periods can adversely affect device reliability.

Parameter	Symbol	Min	Max	Unit
Supply Voltage[*]	—	—	5.5	V
Operating Case Temperature Range[†]	T_C	–40	85	°C
Storage Case Temperature Range	T_{stg}	–40	85	°C
Lead Soldering Temperature/Time	—	—	250/10	°C/s
Relative Humidity (noncondensing)	RH	—	85	%
Minimum Fiber Bend Radius	—	1.00 (25.4)	—	in. (mm)

[*] With V_{EE} connected to –5 V, V_{CC} must be at 0 V; with V_{CC} connected to +5 V, V_{EE} must be at 0 V.

[†] Specification depends upon the code ordered. The device is capable of a cold start at –40 °C; specifications are met after a warm-up time determined by the system thermal design.

Characteristics

Minimum and maximum values specified over operating case temperature range at 50% duty cycle data signal and end of life (EOL). Typical values are measured at beginning-of-life (BOL) room temperature unless otherwise noted.

Table 2. Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Power Supply Voltage[1]	V	4.75	5.0	5.50	V
Power Supply Current Drain	I_{TOTAL}	—	30	130	mA
Input Data Voltage:[2]					
Low	V_{IL}	–1.81	—	–1.47	V
High	V_{IH}	–1.16	—	–0.88	V
Input Transition Time[3]	t_i	—	t/4	—	ns
Transmitter Disable Voltage[4]	V_D	V_{CC} – 2.0	—	V_{CC}	V
Transmitter Enable Voltage	V_{EN}	V_{EE}	—	V_{EE} + 0.8	V
Output Disable Time[5]	t_D	—	—	0.20	µs
Output Enable Time[6]	t_{EN}	—	—	2.00	µs
Laser Bias Voltage[7]	V_B	0.01	0.06	0.70	V
Laser Monitor Voltage (50% duty cycle)[8]	V_{BF}	0.01	0.05	0.20	V

1. With V_{EE} connected to –5 V, V_{CC} must be at 0 V; with V_{CC} connected to +5 V, V_{EE} must be at 0 V.
2. Input measured from V_{CC} with 50 Ω load to (V_{CC} – 2 V). 10K, 10K H, and 100K ECL compatible.
3. Between 10% and 90% (50% duty cycle) where t is the bit period in ns.
4. The transmitter is normally enabled and only requires an external voltage to disable.
5. Time measured from rising edge of disable signal until optical output (laser diode) has turned off.
6. Time measured from falling edge of enable signal until optical output has stabilized at nominal output power level.
7. The laser bias current is obtained by dividing the bias voltage by the 10 Ω current-sensing resistors. (See Figure 1.) When measuring these voltages or using them in conjunction with alarm circuits, use a high-input impedance device.
8. The laser back-facet monitor voltage is a scaled output that tracks the transmitter optical output power.

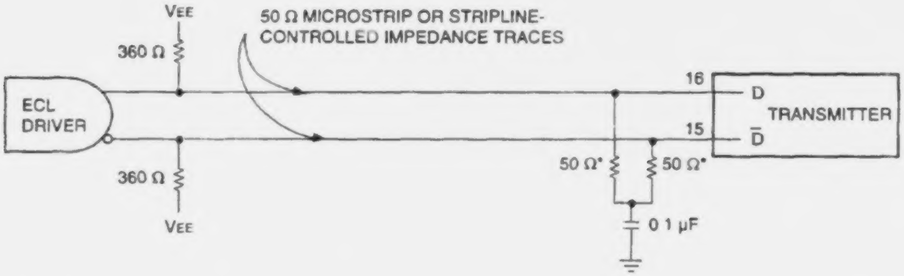
Characteristics (continued)

Table 3. Optical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Average Power Output Options[1]	P_O	See Ordering Information.			dBm
Extinction Ratio[2]	r_E	10	—	—	dB
Optical Rise and Fall Times[3]:					
OC-3/STM-1	t_R, t_F	—	—	1.0	ns
OC-12/STM4	t_R, t_F	—	—	0.5	ns
1062.5 Mbits/s	t_R, t_F	—	—	0.37	ns
Center Wavelength	λ	See Ordering Information.			nm
RMS Spectral Width[4]	$\Delta\lambda$	—	—	4	nm
Side-mode Suppression Ratio[5]	SMSR	30	—	—	dB

1. Output power definitions and measurement per ITU-T Recommendation G.957 and G.958.
2. Ratio of logic 1 to logic 0 power levels.
3. Between 10% and 90% (50% duty cycle)
4. Root-mean-square spectral width accounts for modes up to and including those 20 dB down from the central mode. (Applies to 1241-Type only.)
5. Applies to 1243/1245-Type only

Recommended User Interfaces

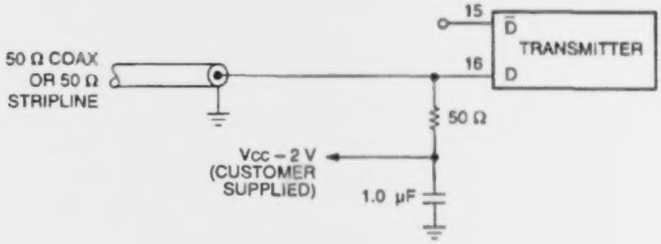

VEE
360 Ω
50 Ω MICROSTRIP OR STRIPLINE-CONTROLLED IMPEDANCE TRACES
ECL DRIVER
16
15
D
D̄
TRANSMITTER
50 Ω*
50 Ω*
360 Ω
VEE
0.1 µF
1-496(C) c

* Locate these components as close to DATA/$\overline{\text{DATA}}$ inputs as possible.

Note: The 1241 gigabit version does not require the external 50 Ω terminations since this termination is included inside the module.

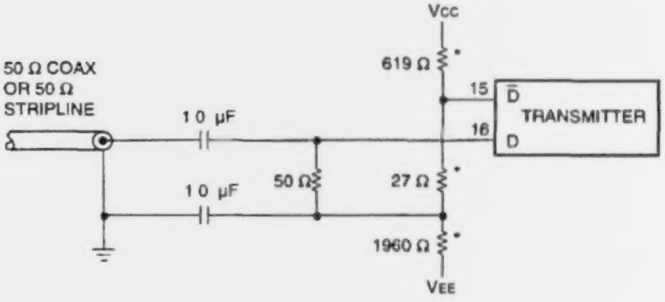
Figure 2. dc-Coupled, Differential Input

Recommended User Interfaces (continued)


15
D̄
TRANSMITTER
16
D
50 Ω COAX
OR 50 Ω
STRIPLINE
50 Ω
Vcc – 2 V
(CUSTOMER
SUPPLIED)
1.0 µF
1-497(C)

Note: Input can also be connected to $\overline{\text{DATA}}$*, unused input pin remains unconnected.*
(622 Mbits/s and below only.)

Figure 3. dc-coupled, Single-Ended Input


Vcc
619 Ω *
50 Ω COAX
OR 50 Ω
STRIPLINE
15
D̄
TRANSMITTER
16
D
1 0 µF
1 0 µF
50 Ω
27 Ω *
1960 Ω *
VEE
1-498(C)

* This network introduces a slight offset between DATA and $\overline{\text{DATA}}$, which turns the laser transmitter off when there is no data present at the inputs. (622 Mbits/s and below only.)

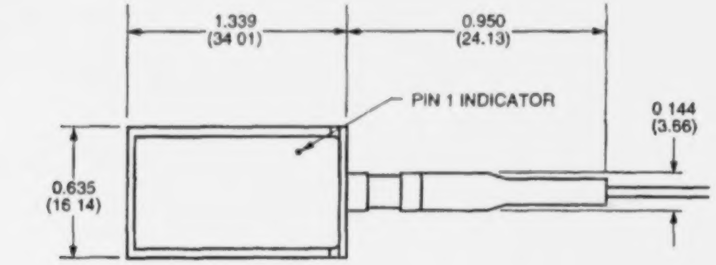
Figure 4. ac-Coupled, Single-Ended Input

Qualification and Reliability

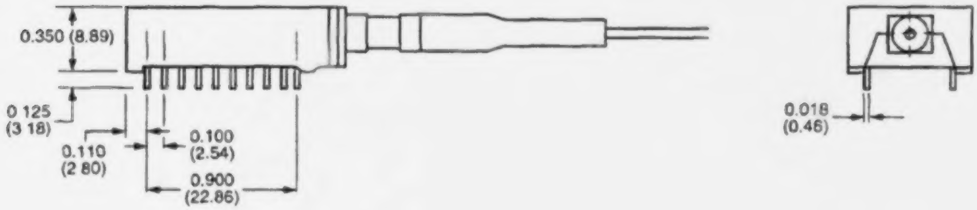
To help ensure high product reliability and customer satisfaction, Lucent Technologies is committed to an intensive quality program that starts in the design phase and proceeds through the manufacturing process. Optoelectronics modules are qualified to Lucent Technologies internal standards using MIL-STD-883 test methods and procedures and using sampling techniques consistent with Bellcore requirements. The 1241/1243/1245 series of transmitters have undergone an extensive and rigorous set of qualification tests. This qualification program fully meets the intent of Bellcore reliability practices TR-NWT-000468 and TA-NWT-000983. In addition, the design, development, and manufacturing facility of the Optoelectronics unit at Lucent Technologies Microelectronics Group has been certified to be in full compliance with the latest ISO-9001 Quality System Standards.

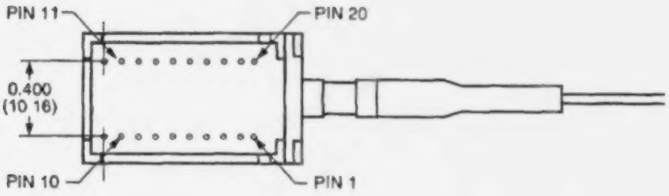
Outline Diagram

Dimensions are in inches and (millimeters). Unless otherwise noted, tolerances are ±0.005 in (±0.127 mm).


1.339
(34.01)
0.950
(24.13)
PIN 1 INDICATOR
0.144
(3.66)
0.635
(16.14)

TOP VIEW


0.350 (8.89)
0.125
(3.18)
0.110
(2.80)
0.100
(2.54)
0.900
(22.86)
0.018
(0.46)


PIN 11
PIN 20
0.400
(10.16)
PIN 10
PIN 1

BOTTOM VIEW

1-967C).a

Laser Safety Information

Class I Laser Product

All versions of the 1241/1243/1245-Type transmitters are Class I laser products per CDRH, 21 CFR 1040 Laser Safety requirements. The 1241/1243/1245-Type transmitters have been certified with the FDA under accession number 8720009. All versions are Class I laser products per IEC 825-1:1993.

CAUTION: Use of controls, adjustments, and procedures other than those specified herein may result in hazardous laser radiation exposure.

This product complies with 21 CFR 1040.10 and 1040.11.
8.8 µm single-mode pigtail with connector
Wavelength = 1.3 µm
Maximum power = 1.6 mW

Notice

Unterminated optical connectors may emit laser radiation.

Do not view with optical instruments.

Table 4. Lucent Transmitters for SONET/SDH Applications

Connector Type	**1.3 µm Transmitter Type**[*]				**1.55 µm Transmitter Type**[†]	
	Short and Intermediate Reach (<2 km and ~15 km)		**Long Reach ~40 km**		**Long Reach ~80 km**	
	OC-3/ STM-1	**OC-12/ STM-4**	**OC-3/ STM-1**	**OC-12/ STM-4**	**OC-3/ STM-1**	**OC-12/ STM-4**
FC-PC	1241FAUC	1241FBUC	1243FAFD	1243FBDC	1245FAFC	1245FBDC
SC	1241CAUC	1241CBUC	1243CAFD	1243CBDC	1245CAFC	1245CBDC

[*] Full SONET/SDH compliance, –40 °C to +85 °C
[†] Full SONET/SDH compliance, –20 °C to +70 °C.

Ordering Information

Table 5. 1241/1243/1245-Type Transmitter Ordering Information

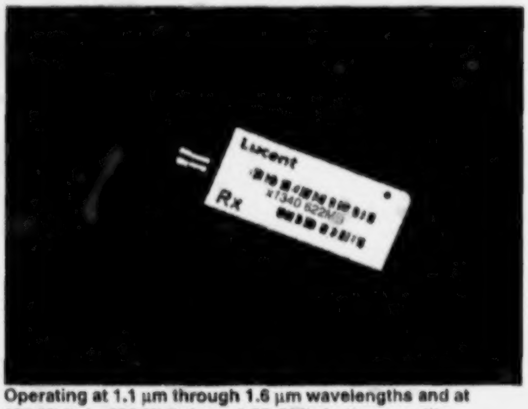
For additional information, contact your Microelectronics Group Account Manager or the following
INTERNET **http://www.lucent.com/micro**, or for Optoelectronics information, **http://www.lucent.com/micro/opto**
E-MAIL **docmaster@micro.lucent.com**
N. AMERICA Microelectronics Group, Lucent Technologies Inc., 555 Union Boulevard, Room 30L-15P-BA, Allentown, PA 18103
1-800-372-2447, FAX 610-712-4106 (In CANADA **1-800-553-2448**, FAX 610-712-4106)
ASIA PACIFIC Microelectronics Group, Lucent Technologies Singapore Pte. Ltd., 77 Science Park Drive, #03-18 Cintech III, Singapore 118256
Tel. (65) 778 8833, FAX (65) 777 7495
CHINA Microelectronics Group, Lucent Technologies (China) Co., Ltd., A-F2, 23/F, Zao Fong Universe Building, 1800 Zhong Shan Xi Road, Shanghai 200233 P. R. China **Tel. (86) 21 6440 0468, ext. 316**, FAX (86) 21 6440 0652
JAPAN Microelectronics Group, Lucent Technologies Japan Ltd., 7-18, Higashi-Gotanda 2-chome, Shinagawa-ku, Tokyo 141, Japan
[illegible]

Data Sheet
January 2000

microelectronics group

Lucent Technologies
Bell Labs Innovations

1340-Type Lightwave Receiver



Operating at 1.1 µm through 1.6 µm wavelengths and at 155 Mbits/s, 622 Mbits/s, or 1.25 Gbits/s, the versatile 1340-Type Receiver is manufactured in a 20-pin, plastic DIP with a multimode fiber pigtail.

Features

- Backward compatible with 1310 receiver family
- Space-saving, self-contained, 20-pin plastic DIP
- Silicon based ICs
- Single 5 V power supply operation including photocurrent monitor capability
- Exceeds all SONET (GR-253-CORE) and ITU-T G.958 jitter requirements
- Wide dynamic range
- Qualified to meet the intent of *Telcordia Technologies*[*] reliability practices
- Operates at data rates of 155 Mbits/s, 622 Mbits/s, or 1.25 Gbits/s
- Positive ECL (PECL) data outputs
- CMOS (TTL) link-status flag output
- Operation at 1.3 µm or 1.55 µm wavelengths
- Operating case temperature range of −40 °C to +85 °C

Applications

- Telecommunications
  - —Inter- and intraoffice SONET/ITU-T SDH
  - —Subscriber loop
  - —Metropolitan area networks
- High-speed data communications

Description

The 1340-Type receiver is designed for use in transmission systems or medium- to high-speed data communications applications at data rates up to 1.25 Gbits/s. Compact packaging, along with wide dynamic range, makes these receivers ideal for both telecommunications and data communications applications.

The following three versions of the receiver are available:

- SONET/SDH compliant with OC-3/STM-1
- SONET/SDH compliant with OC-12/STM-4
- 1.25 Gbits for data applications.

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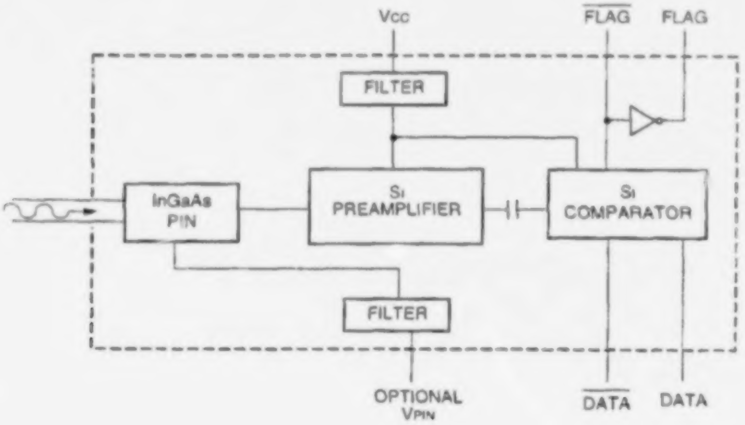
[*] *Telcordia Technologies* is a trademark of Bell Communications Research, Inc.

Description (continued)

The SONET/SDH versions of the receiver are fully compliant with the latest issue of *Telcordia Technologies* GR-253- CORE and the most recent issues of ITU recommendations G.957 and G.958. The 1340-Type receiver requires only a single 5 V power supply for operation. All versions of the receiver are characterized for operation over the case operating range of –40 °C to +85 °C at the appropriate data rate for each version.

Manufactured in a 20-pin DIP, the receivers use a planar, rear illuminated InGaAs PIN photodetector that allows these receivers to be used at wavelengths from 1.1 µm to 1.6 µm. The photocurrent output of the PIN detector is amplified and converted to a voltage by a silicon amplifier. A silicon quantizer provides additional signal amplification, data threshold detection, and PECL data outputs. The incoming optical signal is coupled into the receiver through a 62.5 µm core multimode fiber pigtail. The outer jacket diameter of the pigtail is 900 µm. The receiver can be ordered with the pigtail terminated in an FC/PC, SC, or *ST*® optical connector. Other connectors are available on special order. See your Lucent account representative for ordering conditions and information.

The receiver has differential PECL data outputs and, depending on the version selected, either differential PECL link status flag or complementary CMOS link status flag outputs. The link status flag outputs indicate the presence or absence of a minimum acceptable level of optical input signal.



1-414(C)

Figure 1. Block Diagram

Description (continued)

To help ensure high product reliability and customer satisfaction, Lucent is committed to an intensive quality program that starts in the design phase and proceeds through the manufacturing and shipping process. Optoelectronics subsystems are qualified to Lucent internal standards using MIL-STD-883 test methods and procedures and sampling techniques consistent with *Telcordia Technologies* requirements. The 1340 receiver qualification program meets the intent of *Telcordia Technologies* TR-NWT-000468 and TA-TSY-000983.

Application Information

The 1340 receiver is a highly sensitive fiber-optic receiver. Although the data outputs are digital logic levels (PECL), the device should be thought of as an analog component. When laying out the printed-wiring board (PWB), the 1340 receiver should be given the same type of consideration one would give to a sensitive analog component.

At a minimum, a double-sided printed-wiring board with a large component-side ground plane beneath the receiver must be used. In applications that include many other high-speed devices, a multilayer PWB is highly recommended. This permits the placement of power and ground connections on separate layers, which helps minimize the coupling of unwanted signal noise into the power supplies of the receiver.

Layout Considerations

A fiber-optic receiver employs a very high-gain, wide-bandwidth transimpedance amplifier. The amplifier detects and amplifies signals that are only tens of nA in amplitude. Any unwanted signal currents that couple into the receiver circuitry cause a decrease in the receiver's sensitivity and can also degrade the performance of the receiver's loss of signal (FLAG) circuit

To minimize the coupling of unwanted noise into the receiver, route high-level, high-speed signals such as transmitter inputs and clock lines as far away as possible from the receiver pins. If this is not possible, then the PWB layout engineer should consider interleaving the receiver signal and flag traces with ground traces in order to provide the required isolation.

Noise that couples into the receiver through the power supply pins can also degrade device performance. The application schematics, Figures 3—5, show recommended power supply filtering that helps minimize noise coupling into the receiver. The bypass capacitors should be high-quality ceramic devices rated for RF applications. They should be surface-mount components placed as close as possible to the receiver power supply pins. The ferrite bead should have as high an impedance as possible in the frequency range that is most likely to cause problems. This will vary for each application and is dependent on the signaling frequencies present on the application circuit card. Surface-mount, high-impedance beads are available from several manufacturers.

Data and Flag Outputs

The data outputs of the 1340 receiver are driven by open-emitter NPN transistors which have an output impedance of approximately 7 Ω. Each output can provide approximately 50 mA maximum output current. Due to the high switching speeds of ECL outputs, transmission line design must be used to interconnect components. To ensure optimum signal fidelity, both data outputs (DATA and $\overline{\text{DATA}}$) should be terminated identically. The signal lines connecting the data outputs to the next device should be equal in length and should have matched impedances.

Controlled impedance stripline or microstrip construction must be used to preserve the quality of the signal into the next component and to minimize reflections back into the receiver. Excessive ringing due to reflections caused by improperly terminated signal lines makes it difficult for the component receiving these signals to decipher the proper logic levels and may cause transitions to occur where none were intended. Also, by minimizing high frequency ringing due to reflections caused by improperly designed and terminated signal lines, possible EMI problems can be avoided. The applications sections in the Signetics* *ECL 10K/100K* Data Manual or the National Semiconductor† *ECL Logic Databook and Design Guide* provide excellent design information on ECL interfacing.

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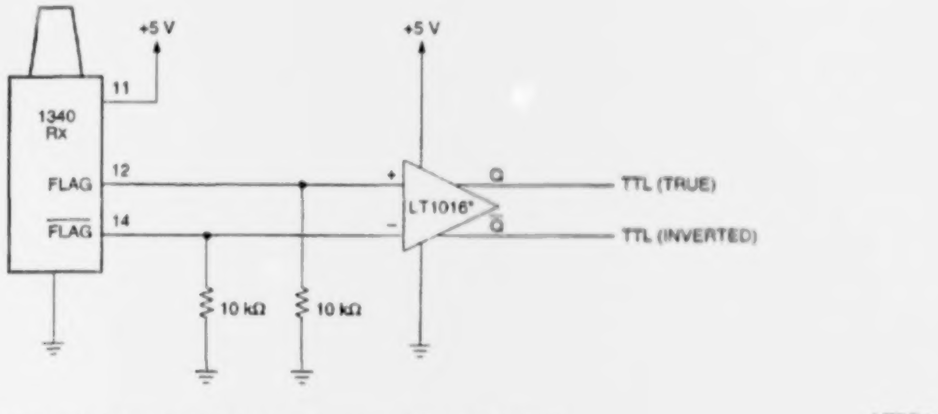
* *Signetics* is a registered trademark of Signetics Corp.

† *National Semiconductor* is a registered trademark of National Semiconductor Corporation

Data and Flag Outputs (continued)

The FLAG and $\overline{\text{FLAG}}$ outputs of the OC-3/STM-1 155 Mbits/s version of the 1340 receiver are PECL logic levels driven by open emitter transistors with the same characteristics as the data outputs. These outputs must be properly terminated in order to obtain the correct logic levels. Since the FLAG function is basically a dc switch that indicates the loss of optical input signal, it can be interfaced to much slower TTL or CMOS logic circuits.

The circuit shown in Figure 2 provides one example of how to create a TTL logic output from the PECL FLAG output signal. The outputs of the LT1016 are TTL-compatible and provide both true and inverted logic levels. The Q output of this circuit will be a TTL high (>2.5 V) when the 1340 is receiving an optical signal greater than the FLAG switching threshold and will be a TTL low (<0.4 V) whenever the optical signal is absent or is below the FLAG switching threshold. The FLAG and $\overline{\text{FLAG}}$ outputs of the OC-12/STM-4 and 1.25 Gbits/s receivers are 5 V TTL logic level compatible. The FLAG output is provided directly by the comparator IC. However, the FLAG output is derived from the $\overline{\text{FLAG}}$ output through an inverter. Excessive loading of the $\overline{\text{FLAG}}$ output can cause the FLAG output to malfunction.



* Part available from Linear Technology Corporation of Milpitas, CA 95035.

Figure 2. Converting PECL FLAG Outputs to TTL

Pin 10

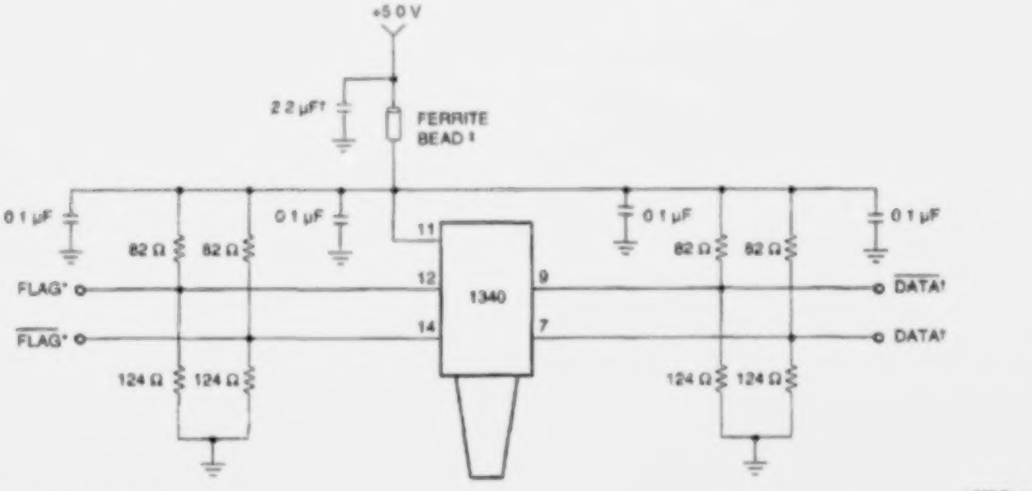
Pin 10 on the 1340-Type receiver is a not internally connected (NIC) pin. This definition allows the 1340 to be used in most customer 20-pin receiver module applications. Customer's printed-wiring boards that are designed with ground, +5 V, –5 V, or no connection to this pin are all acceptable options. For those applications that require monitoring the photocurrent of the PIN photodetector for power monitoring purposes, there are versions of the 1340 that require +5 V or –5 V applied to Pin 10. Check Tables 4 and 5 for ordering information.

Recommended User Interface

The 1340 receiver is designed to be operated from a 5 V power supply and provides raised or pseudo-ECL (PECL) data outputs. Figures 3 and 4 show two possible application circuits for the 1340 receiver. Figure 3 represents an application for the version with PECL FLAG outputs while Figure 4 shows a possible application for the version with the TTL-compatible FLAG outputs.

In both instances, the DATA outputs are terminated with a Thévenin equivalent circuit, which provides the equivalent of a 50 Ω load terminated to (Vcc – 2 V). A single 50 Ω resistor terminated to (Vcc – 2 V) could also be used, but this requires a second power supply. Other methods of terminating ECL-type outputs are discussed in the references previously mentioned.

Figure 5 shows an example of a circuit that can be used to interface the PECL outputs of the 1340 receiver with a device which requires true, negative voltage ECL inputs. The 100314 is an ECL line receiver and is shown here only as an example to demonstrate this coupling procedure. The DATA lines are terminated in a 50 Ω equivalent impedance but are ac-coupled to the 100314. The capacitive coupling isolates and permits level shifting of the positive DATA outputs of the receiver to the proper negative level required by the inputs of the 100314. The VBB output of the 100314 provides the reference voltage required to center the voltage swing of the DATA signals around the input switching threshold of the 100314. The Thévenin equivalent of the 166 Ω and 250 Ω resistor pair is 100 Ω, which, in parallel with the 100 Ω resistor connected to VBB, results in a 50 Ω equivalent impedance for the load on each of the data lines. Alternatively, if there is no VBB reference available, a second pair of 166 Ω/250 Ω resistor networks could be used on the data lines on the 100314 side of the coupling capacitor.

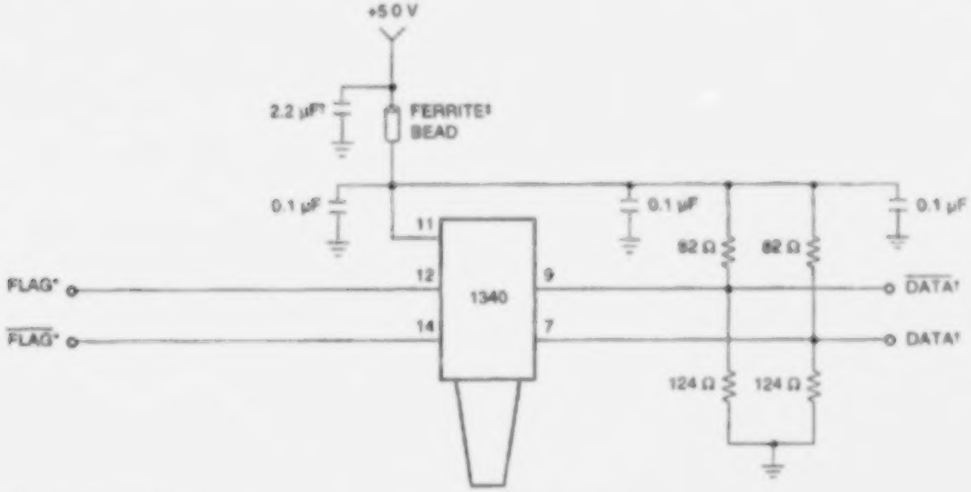


* 50 Ω to (Vcc – 2) V.
† DATA and $\overline{\text{DATA}}$ are 50 Ω impedance transmission lines; both lines can be ac- or dc-coupled into the next device.
‡ Fair-Rite Products Corporation part number 2743037447 or equivalent.

Note. All unused outputs must be terminated as shown. All resistors are 1/8 W, thin-film, ceramic chips. All capacitors are 25 Vdc, ceramic X7R, or equivalent.

Figure 3. Interfacing to the 155 Mbits/s 1340 Receiver

Recommended User Interfaces (continued)


+5.0 V
2.2 µF‡
FERRITE‡
BEAD
0.1 µF
0.1 µF
0.1 µF
11
12
14
9
7
1340
82 Ω
82 Ω
124 Ω
124 Ω
FLAG*
$\overline{\text{FLAG}}$*
$\overline{\text{DATA}}$†
DATA†

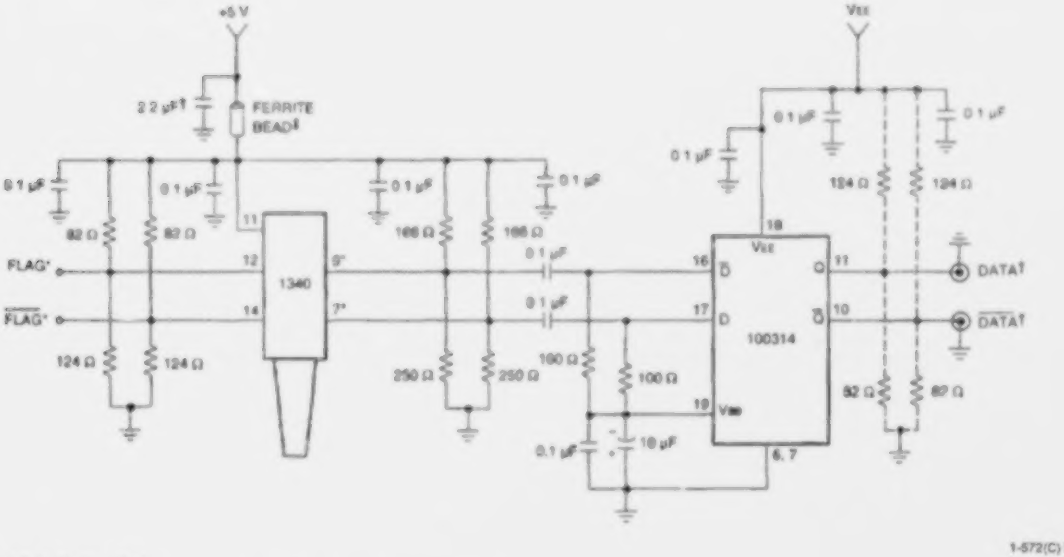
* TTL (CMOS) compatible level

† DATA and $\overline{\text{DATA}}$ are 50 Ω impedance transmission lines; both lines can be ac- or dc-coupled into the next device

‡ Fair-Rite Products Corporation part number 2743037447 or equivalent.

1-600(C) c

Figure 4. Interfacing to the 622 Mbits/s and 1.25 Gbits/s 1340 Receivers


+5 V
VEE
2.2 µF†
FERRITE
BEAD‡
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
0.1 µF
82 Ω
82 Ω
124 Ω
124 Ω
166 Ω
166 Ω
250 Ω
250 Ω
100 Ω
100 Ω
10 µF
124 Ω
124 Ω
82 Ω
82 Ω
FLAG*
$\overline{\text{FLAG}}$*
11
12
14
9*
7*
1340
18
VEE
16
$\overline{\text{D}}$
17
D
19
VBB
100314
11
Q
10
$\overline{\text{Q}}$
6, 7
DATA†
$\overline{\text{DATA}}$†

1-572(C) b

* 50 Ω to (VCC – 2) V.

† 50 Ω to –2 V DATA and $\overline{\text{DATA}}$ are 50 Ω impedance transmission lines.

‡ Fair-Rite Products Corporation part number 2743037447 or equivalent.

Figure 5. Interfacing the 155 Mbits/s 1340 Receiver to a True ECL Circuit

Pin Information

Table 1. Pin Descriptions

Pin Number	Description
1	Ground
2	Ground
3	Ground
4	Ground
5	No User Connection*
6	Ground
7	DATA
8	Ground
9	$\overline{\text{DATA}}$
10	N/C or Optional V_{PIN}
11	V_{CC} (5 V)
12	FLAG†
13	Ground
14	$\overline{\text{FLAG}}$
15	Ground
16	Ground
17	No User Connection*
18	No User Connection*
19	No User Connection*
20	No User Connection*

* Pins designated as no user connection are not connected internally within the receiver. However, to allow for future functional upgrades, it is recommended that the user not make any connections to these pin positions.

† The link-status flag is a logic output that indicates the presence or absence of a minimum acceptable level of optical input. A logic high on FLAG indicates the presence of a valid optical signal.

Handling Precautions

Mounting and Connections

The pigtail consists of a 39 in. ± 4 in. (1 m ± 10 cm), 62.5 μm core/125 μm cladding multimode fiber. The standard fiber has a 0.036 in. (914 μm) diameter tight-buffered outer jacket. The minimum fiber bending radius during operation is 1.0 in. (25.4 mm).

Electrostatic Discharge

Caution: **This device is susceptible to damage as a result of electrostatic discharge (ESD). Take proper precautions during both handling and testing. Follow *EIA** Standard *EIA*-625.**

Although protection circuitry is designed into the device, take proper precautions to avoid exposure to ESD.

Lucent employs a human-body model (HBM) for ESD susceptibility testing and protection-design evaluation. ESD voltage thresholds are dependent on the critical parameters used to define the model. A standard HBM (resistance = 1.5 kΩ, capacitance = 100 pF) is widely used and, therefore, can be used for comparison purposes. The HBM ESD threshold established for the 1340 receiver is ±1000 V.

Receiver Processing

The 1340-type receiver devices can withstand normal wave-soldering processes. The complete receiver module is not hermetically sealed; therefore, it should not be immersed in or sprayed with any cleaning solution or solvents. The process cap and fiber pigtail jacket deformation temperature is 85 °C. The receiver pins can be wave-soldered at maximum temperature of 250 °C for 10 seconds

Installation Considerations

Although the receiver features a robust design, care should be used during handling. The optical connector should be kept free from dust, and the process cap should be kept in place as a dust cover when the device is not connected to a cable. If contamination is present on the optical connector, the use of canned air with an extension tube should remove any debris. Other cleaning procedures are identified in the technical note, *Cleaning Fiber-Optic Assemblies* (TN95-010LWP).

* *EIA* is a registered trademark of Electronic Industries Association.

Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are absolute stress ratings only. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operations section of the data sheet. Exposure to absolute maximum ratings for extended periods can adversely affect device reliability.

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V_{CC}	—	5.5	V
Operating Case Temperature Range	T_C	–40	85	°C
Storage Case Temperature Range	T_{stg}	–40	85	°C
Lead Soldering Temperature/Time	—	—	250/10	°C/s
Operating Wavelength Range	λ	1.1	1.6	µm
Minimum Fiber Bend Radius	—	1.0 (25.4)	—	in. (mm)

Operating Characteristics

Minimum and maximum values specified over operating case temperature range and end-of-life (EOL). Typical values are measured at beginning-of-life (BOL) room temperature unless otherwise noted.

Table 2. Optical Characteristics

Parameter	Symbol	Data Rate (Mbits/s)	Min	Typ*	Max	Unit
Measured Average Sensitivity*	P_R	155	—	–38	–36	dBm
		622	—	–32	–29	dBm
		1250	—	–28	–24	dBm
Maximum Input Power*	P_{MAX}	155	–3.0	0	—	dBm
		622	–6.0	–3.0	—	dBm
		1250	–3.0	–2.0	—	dBm
Link Status Switching Threshold:						
Decreasing Light Input	LST_D	155	–53.0	–40	–36.0	dBm
		622	–45.0	–34	–28.0	dBm
		1250	–36.0	–31.0	–26.0	dBm
Increasing Light Input	LST_I	155	–52.5	–38	–35.5	dBm
		622	–45.5	–31	–27.5	dBm
		1250	–35.5	–29.0	–25.5	dBm
Hysteresis	HYS	All Data Rates	0.5	3.0	6.0	dBm
Detector Responsivity	R	All Data Rates	0.7	0.8	1.2	A/W

* For 1×10^{-10} BER with an optical input using a $2^{23} - 1$ pseudorandom word having a 50% average duty cycle.

Operating Characteristics (continued)

Table 3. Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
dc Power Supply Voltage	V_{CC}	4.75	5.0	5.25	V
PIN Photodetector Supply Voltage (Pin 10)*	V_{PIN}	4.75	5.0	5.25	V
	V_{PIN}	–5.25	–5.0	–4.75	V
Power Supply Current	I_{CC}	—	80	150	mA
	I_{PIN}	—	—	1	mA
Output Data Voltage:†					
Low	V_{OL}	V_{CC} – 1.81	V_{CC} – 1.70	V_{CC} – 1.62	V
High	V_{OH}	V_{CC} –1.025	V_{CC} – 0.95	V_{CC} – 0.88	V
Output Rise Time/Fall Time:					
OC-3/STM-1 Versions	t_R/t_F	—	700	1400	ps
OC-12/STM-4 Versions	t_R/t_F	—	350	400	ps
Output Flag Voltage:					
OC-3/STM-1 Versions:‡					
Low	V_{FL}	—	V_{CC} – 1.90	V_{CC} – 1.65	V
High	V_{FH}	V_{CC} – 1.025	V_{CC} – 1.0	—	V
OC-12/STM-4 Versions:‡					
Low	V_{FL}	0	—	0.5	V
High	V_{FH}	V_{CC} – 0.5	—	V_{CC}	V
Output Data Current:†					
Low	I_{OL}	—	5	50	mA
High	I_{OH}	—	20	50	mA
Output Flag Current:					
OC-3/STM-1 Versions:					
Low	I_{OL}	—	5	50	mA
High	I_{OH}	—	20	50	mA
OC-12/STM-4 Versions:					
Low	I_{OL}	0	10	15	mA
High	I_{OH}	0	10	15	mA

* Customers have the option for either a +5 V or –5 V supply

† Measured from V_{CC} with a 50 Ω load to (V_{CC} – 2) V

‡ Internally terminated CMOS output

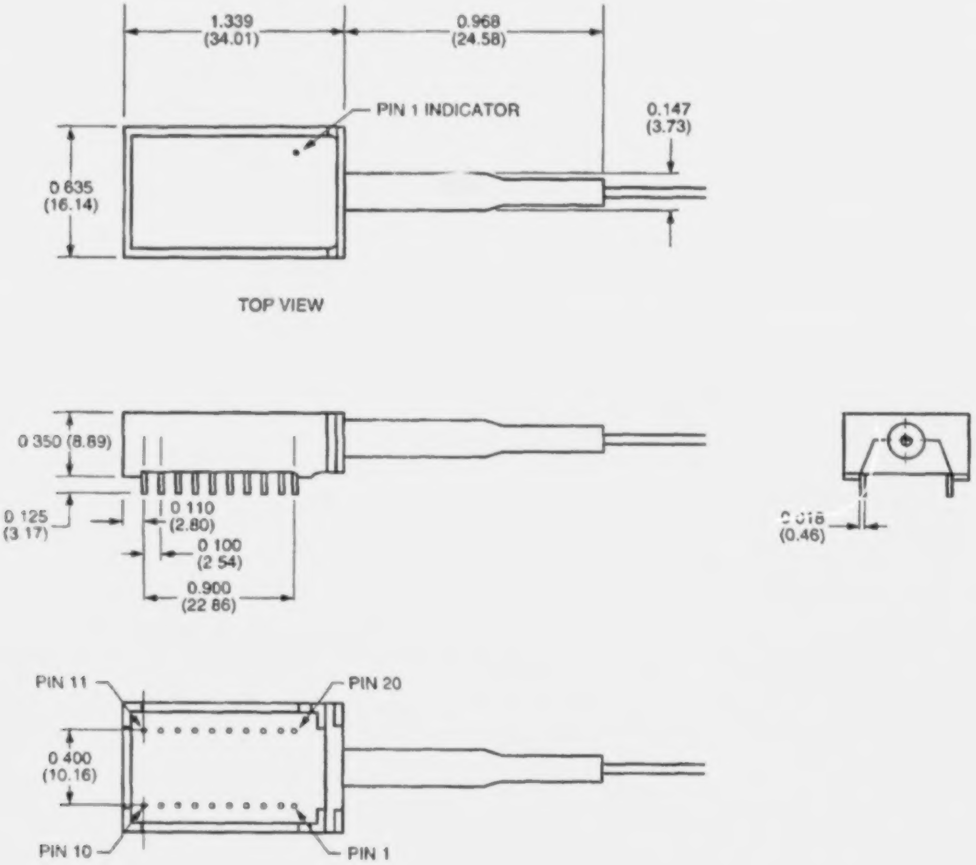
Qualification Tests and Reliability

To help ensure high product reliability and customer satisfaction, Lucent Technologies is committed to an intensive quality program that starts in the design phase and proceeds through the manufacturing process. Optoelectronics modules are qualified to Lucent Technologies internal standards using MIL-STD-883 test methods and procedures and using sampling techniques consistent with *Telcordia Technologies* requirements. The 1340-Type receivers have undergone an extensive and rigorous set of qualification tests. This qualification program fully meets the intent of *Telcordia Technologies* reliability practices TR-NWT-000468 and TA-NWT-000983. In addition, the design, development, and manufacturing facility of the Optoelectronics unit at Lucent Technologies Microelectronics Group has been certified to be in full compliance with the latest *ISO**-9001 Quality System Standards.

* *ISO* is a registered trademark of The International Organization for Standardization.

Outline Diagram

Dimensions are in inches and (millimeters). Unless noted otherwise, tolerances are 0.005 in. (0.127 mm).


1.339
(34.01)
0.968
(24.58)
PIN 1 INDICATOR
0.147
(3.73)
0.635
(16.14)
TOP VIEW
0.350 (8.89)
0.125
(3.17)
0.110
(2.80)
0.100
(2.54)
0.900
(22.86)
0.018
(0.46)
PIN 11
PIN 20
0.400
(10.16)
PIN 10
PIN 1

1-988(C)

Ordering Information

Table 4. OC-3/STM-1 Receiver Versions

Device Code	Connector	Pin 10 Requirements	Comcode
1340FMPC	FC-PC	No Internal Connection	108162322
1340CMPC	SC		108354408
1340TMPC	*ST*		108572264
1340FAPC	FC-PC	Requires +5 V or –5 V (Used for photocurrent monitoring)	108468687
1340CAPC	SC		108359175
1340TAPC	*ST*		108572249

Table 5. OC-12/STM-4 Receiver Versions

Device Code	Connector	Pin 10 Requirements	Comcode
1340FNPC	FC-PC	No Internal Connection	108155680
1340CNPC	SC		108354416
1340TNPC	*ST*		108155755
1340FBPC	FC-PC	Requires +5 V or –5 V (Used for photocurrent monitoring)	108155672
1340CBPC	SC		108468679
1340TBPC	*ST*		108572256

Table 6. 1.25 Gbits/s Receiver Versions

Device Code	Connector	Pin 10 Requirements	Comcode
1340FCPC	FC-PC	Requires +5 V or –5 V	108400342
1340CCPC	SC		108400334

Table 7. Related Products

Description	Document Number
1241/1243/1245-Type Receivers for SONET/SDH Applications	DS99-073LWP
1345-Type Receiver with Clock Recovery and Data Retiming	DS00-099OPTO

For additional information, contact your Microelectronics Group Account Manager or the following

INTERNET:	**http://www.lucent.com/micro**, or for Optoelectronics information, **http://www.lucent.com/micro/opto**
E-MAIL	**docmaster@micro.lucent.com**
N AMERICA:	Microelectronics Group, Lucent Technologies Inc , 555 Union Boulevard, Room 30L-15P-BA, Allentown, PA 18103 **1-800-372-2447**, FAX 610-712-4106 (In CANADA **1-800-553-2448**, FAX 610-712-4106)
ASIA PACIFIC	Microelectronics Group, Lucent Technologies Singapore Pte Ltd , 77 Science Park Drive, #03-18 Cintech III, Singapore 118256 **Tel. (65) 778 8833**, FAX (65) 777 7495
CHINA	Microelectronics Group, Lucent Technologies (China) Co , Ltd , A-F2, 23/F, Zao Fong Universe Building, 1800 Zhong Shan Xi Road, Shanghai 200233 P R China **Tel. (86) 21 6440 0468, ext. 316**, FAX (86) 21 6440 0652
JAPAN	Microelectronics Group, Lucent Technologies Japan Ltd , 7-18, Higashi-Gotanda 2-chome, Shinagawa-ku, Tokyo 141, Japan **Tel. (81) 3 5421 1600**, FAX (81) 3 5421 1700
EUROPE.	Data Requests MICROELECTRONICS GROUP DATALINE **Tel. (44) 7000 582 368**, FAX (44) 1189 328 148 Technical Inquiries OPTOELECTRONICS MARKETING: **(44) 1344 865 900** (Ascot UK)

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microelectronics group

Lucent Technologies
Bell Labs Innovations

January 2000
DS00-098OPTO (Replaces DS99-072LWP)

OPTOELECTRONICS

NORTEL
NETWORKS

DATASHEET

LCV 75 SERIES

1300nm Mini-DIL TRANSMITTER

Features

Wavelength 1300nm.

One piece fibre alignment.

High performance design for high volume feeder and distribution networks.

Nortel's GaInAsP laser chip designed for extended temperature operation.

Isolated internal fast InGaAs monitor photodiode.

Proven reliability and Bellcore TA-NWT-000983 capability.

Hermetically sealed package.

8/125µm cladding mode stripped fibre pigtail.

Maximum data rate in excess of 622Mb/s.

Footprint compatible with 14 pin DIL series.

Description

The LCV 75 series are optical transmitters suitable for 155/622 Mbit/s Long / Intermediate reach SONET,and Long/Short Haul SDH single mode applications They use Nortel's one piece fibre alignment technology offering high stability and reliability. Nortel's unsurpassed quality and reliability are featured in a rugged, hermetically sealed ceramic package, and fully tested for environmental integrity.

The laser chip has been specifically developed for operation over an extended temperature range and the product is capable of satisfying the requirements of the Bellcore quality specification TA - NWT - 000983.

The rear facet monitor diode has been optimised to provide a fast response enabling either conventional mean power control or individual bit monitoring at speeds in excess of 622 Mbit/s.

The LCV series is compatible with the PTAV miniDIL receiver.

Parameters	O/P code		
Optical output power (peak) (see ordering information)	A	0.1	mW
	B	0.2	mW
	C	0.5	mW
	D	1.0	mW
	E	1.3	mW
	F	1.5	mW
	G	2.0	mW

Characteristics

Case Temperature	-40°C	25°C			85°C	
Parameter	Min	Min	Typ	Max	Max	Unit
Threshold current (I_{th})	8		23	26	50	mA
Drive current above I_{th} (ýI_f)	10		19		45	mA
Forward voltage (V_f)					1.6	V
Wavelength Code C (OC3IR/STM.S-1.1 -40/85°C) Code D (OC3LR/STM L-1.1 0/85°C) Code E (OC3LR/STM.L-1.1 -20/70°C) Code F (OC12IR/STM.S -4.1 -40/85°C)		1292 1292 1304 1304		1325 1304 1312 1325		nm nm nm nm
Spectral width (RMS)			2	2.5	2.5	nm
Temp. depend. of track error rel 25°C±1					±1	dB
Monitor photocurrent (I_m)		0.2	0.4	0.6		mA
Monitor dark current (I_d)			2	15	100	nA
Monitor capacitance			2.8			pF
Optical rise/fall time			300	500		ps
Slope saturation		+10		-35	-35	%
Spontaneous to peak power ratio					13	dB

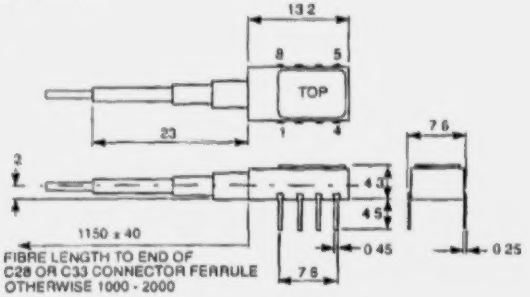
DATASHEET

Absolute Ratings

Parameter	Min	Max	Unit
Operating temperature (case)	-40	+85	°C
Storage temperature	-40	+85	°C
Forward current (-40°C)		I_{th} + 60	mA
Forward current (85°C)		I_{th} + 100	mA
Reverse voltage		1	V
Monitor bias voltage		-5	V
Fibre bend radius	35		mm

Outline Drawing

Nominal dimensions in mm



Connections

Pin	1	Not connected	Pin	5	Photodiode anode
	2	Package ground		6	Laser cathode
	3	Not connected		7	Laser anode
	4	Photodiode cathode		8	Not connected

Ordering Information

LCV75 [wavelength code] [power code] - 98 [connector type]

wavelength code	power code	connector type
C	A	SC = C28
D	B	FCPC = C33
E	C	no suffix = 2 5mm o.d. ceramic ferrule
F	D	
	E	
	F	
	G	

e g. **LCV75CB - 98C28**

Applications Note AN0020 and Qualification Report QR1241 are also available for this device

PB0020 Issue 1 September 1997

INVISIBLE LASER
RADIATION - DO NOT STARE
INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL
INSTRUMENTS
CLASS 3A LASER PRODUCT

REFERENCE IEC 825 - 1 1993

DANGER

CAUTION - USE OF CONTROLS OR
ADJUSTMENTS OR PERFORMANCE
OF PROCEDURES OTHER THAN
THOSE SPECIFIED HEREIN MAY
RESULT IN HAZARDOUS
RADIATION EXPOSURE

CAUTION
STATIC SENSITIVE
DEVICE
OBSERVE PRECAUTIONS

Certificate No. FM 15040

Certificate No. EMS 35100

Optoelectronics

BRIXHAM ROAD,
PAIGNTON,
DEVON, TQ4 7BE

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OPTOELECTRONICS

NORTEL NETWORKS

DATASHEET

PTAV SERIES

FIBRE OPTIC RECEIVER

Features

Wavelength range 1200 - 1600nm.

One piece fibre alignment with no distortion material system.

InGaAs PIN.

Low noise amplifier.

OC1, OC3& OC12 versions available.

Proven reliability and Bellcore TA-NWT-000983 capability.

Hermetically sealed package.

Description

The PTAV series are optical receivers suitable for bit rates from 16 to 622 Mbit/s long and intermediate reach SDH/SONET/ATM single mode applications They use Nortel's one piece fibre alignment technology offering high stability and reliability and are capable of satisfying the requirements of the Bellcore quality specification TA-NWT-00983. Nortel's unsurpassed quality and reliability are featured in a rugged, hermetically sealed, ceramic package fully tested for environmental integrity.

The receivers are designed to be physically small and their 8 pin mini DIL packages are near pin-compatible with industry standard 14 pin DIL devices. The optical element is an InGaAs PIN photodiode coupled to a multimode fibre pigtail, and an integral transimpedance amplifier with AGC is featured. Operation from either dual +5 / -5.2V supplies or single +5V supply is specified by selecting a PTAV**L or PTAV**C respectively.

The PTAV series is compatible with the LCV mini DIL transmitter.

Characteristics

Conditions Ambient temperature 22°C
Load impedance 50Ω
Wavelength 1300nm nom.

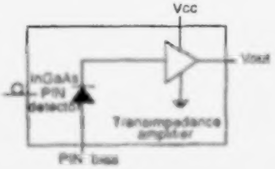
		Sensitivity		Overload 0V PIN bias PTAV**C only		-5.2V PIN bias PTAV**C&L		Band width	Trans imped
Application	**Device code**	**Min dBm**	**Typ dBm**	**Min dBm**	**Typ dBm**	**Min dBm**	**Typ dBm**	**Typ MHz**	**Typ kΩ**
16Mb/s	PTAV50*	-44	-47	-6	-3	-3	0	55	28
45/50 Mb/s OC1	PTAV50*	-40	-43	-6	-3	-3	0	55	28
68Mb/s	PTAV50*	-39.3	-42 3	-6	-3	-3	0	55	28
90Mb/s	PTAV50*	-38.4	41.4	-6	-3	-3	0	55	28
STM/OC3	PTAV155*	-39	-42	-6	-3	0	1	100	13
STM/OC12	PTAV622*	-33	-34	-6	-3	0	1	400	5
Parameter		**Min**			**Typ**			**Unit**	
Detector responsivity		0.8			0.9			A/W	
Total leakage current					<1			nA	

Note - 1 Sensitivity at BER = 10^{-10} is measured using a rms noise voltage test
Transimpedance values apply when AGC function is fully off
2 A device with the suffix 'C' is specified to deliver the above overload performances under single supply rail (0V PIN bias) and dual supply rail (-5 2V PIN bias) conditions A device with the suffix 'L' is specified for overload under dual supply rail (-5 2V PIN bias) conditions only

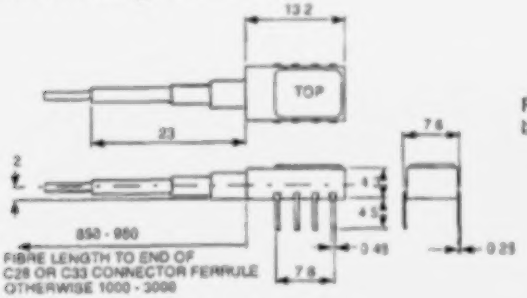
Absolute Ratings

Parameter	Min	Max	Unit
Operating and storage temperature	-40	+85	°C
Supply voltage V_{cc}	+4.5	+5.5	V
PIN bias	-15	+0.5	V
Fibre bend radius	30		mm

Block Diagram

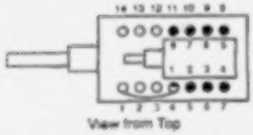

Vcc
Vout
InGaAs PIN detector
Transimpedance amplifier
PIN bias

Outline Drawing Dimensions in mm


13 2
TOP
23
7 6
2
4 2
4 5
0 46
0 25
850 - 950
FIBRE LENGTH TO END OF
C28 OR C33 CONNECTOR FERRULE
OTHERWISE 1000 - 3000
7 6

Pin	
1	Photodiode bias
2	Case ground
3	Case ground
4	Output
5	Case ground
6	Case ground
7	+ve supply
8	Case ground

Comparison with 14 Pin Footprint


14 13 12 11 10 9 8
8 7 6 5
1 2 3 4
1 2 3 4 5 6 7
View from Top

A link is required to connect
Photodiode bias to pin 1
All other connections remain the same

This Product (8 Pin)		Previous Generation (14 Pin)	
		Pin 1	Photodiode
		2	Case ground
		3	Case ground
Pin 1	Photodiode bias	4	Not connected
2	Case ground	5	Case ground
3	Case ground	6	Case ground
4	Output	7	Output
5	Case ground	8	Case ground
6	Case ground	9	Case ground
7	+ve supply	10	+ve supply
8	Case ground	11	Case ground
		12	Case ground
		13	Case ground
		14	Case ground

CAUTION
STATIC SENSITIVE DEVICE
OBSERVE PRECAUTIONS

Certificate No. FM 15040

Certificate No EMS 35100

Ordering Information

PTAV [operating speed] C - 98 [connector type]
L

C28 = SC
C33 = FCPC
no suffix = 2.5mm o.d. ceramic ferrule

Example .- **PTAV155C - 98C33** is a 155Mbit receiver specified for operation with dual +5V/-5.2V or single +5V power supply with FCPC connector

PB0035 Issue 2 February 1998

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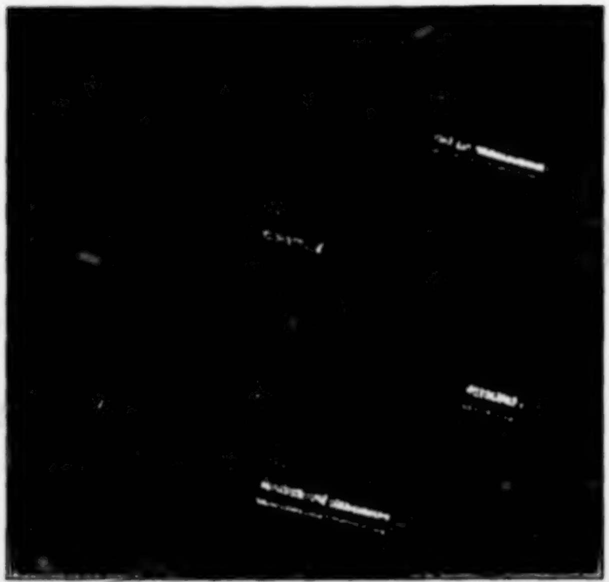
Optoelectronics
BRIXHAM ROAD,
PAIGNTON,
DEVON, TQ4 7BE

OCP

STX / SRX

SONET/SDH Transmitters & Receivers



Features

☑ *Fully compliant with SONET/SDH OC-1 to OC-24 (52 Mb/s, 156 Mb/s, 622 Mb/s & 1.25 Gb/s) specifications*

☑ *Long Reach 1310 nm (40 km distance), Long Reach 1550 nm (80 km distance) as well as Intermediate Reach (15 km)*

☑ *Eye Safe (Class I Laser Safety)*

☑ *- 40°C to +85°C Operating Temperature (option "A")*

☑ *Multi-sourced 20-pin DIP metal package*

☑ *FC, ST, SC-connectorized fiber pigtails or Integral FC , SC or ST connector receptacle*

Description

The STX and SRX modules are laser transmitters and receivers designed to meet or exceed the SONET/SDH optical interface requirements at OC-1 (52 Mb/s), OC-3/STM-1 (155 Mb/s), OC-12/STM-4 (622 Mb/s), and OC-24 (1.25 Gb/s) data rates. Many performance versions are available which are fully compliant with Intermediate Reach and Long Reach specifications at 1300 nm or 1550 nm wavelength. All modules satisfy Class I Laser Safety requirements in accordance with the US FDA/CDRH and international IEC-825 standards.

The transmitter features an Automatic Power Control (APC) circuit to maintain the optical output power at a constant level against variations in ambient temperature and device aging. A Laser Disable control input is also provided. The laser bias current and back-facet light output can also be monitored. The receiver features a low noise GaAs transimpedance IC with AGC capability to provide an extremely wide dynamic range.

A Signal Detect function which indicates loss of optical input is also provided.

The transmitter can be operated with a single supply, either +5 V or - 5 V. The receiver can be operated with dual +5 V and - 5 V supply, or single +5 V supply, or single - 5 V supply. The electrical interface signals are differential ECL or PECL. If TTL interfaces for SIGNAL DETECT outputs are required, the SRX-12-L receivers can be used (please refer to the SRX-12-L data sheet).

Both modules operate over an operating temperature range of 0°C to +70°C ("B" option) or -40°C to +85°C ("A" option). They are housed in a 20-pin dual-in-line metal package with integral ST, FC or SC connector receptacle or fiber pigtail (single mode fiber for the transmitter and 50 μm multimode fiber for the receiver). The fiber pigtail is terminated with ST, FC or SC connector.

Absolute Maximum Ratings

Parameter		Symbol	Minimum	Maximum	Units
Storage Temperature		T_{st}	- 40	+ 85	°C
Operating Temperature	"A" option	T_{op}	- 40	+ 85	°C
	"B" option		0	+ 70	
Operating & Storage Humidity		-	-	85	%
Supply Voltage		V_{CC} - V_{EE}	0	+ 6.0	V
Input Voltage (to Transmitter)		V_{in}	V_{EE}	V_{CC}	V
Lead Soldering Temperature & Time		-	-	260°C, 10 sec	

OC-1 Transmitter & Receiver: STX-01 & SRX-01

Transmitter Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	5	52	100	Mb/s
Average Optical Output Power (coupled into single mode fiber), 50% duty cycle	HP	P_o	- 3.0	0	+2.0	dBm
	L0		- 5.0	- 3.0	0	
	L1		- 8.0	- 5.0	- 2.0	
	L2		- 12.0	- 8.0	- 5.0	
	L3		- 15.0	- 11.0	- 8.0	
Extinction Ratio		P_{hi}/P_{lo}	10	-	-	dB
Center Wavelength	IR (Intermediate Reach)	λ_c	1261	1310	1360	nm
	LR1 (Long Reach 1310 nm)		1280	1310	1335	
	LR2 (Long Reach 1550 nm)		1480	1550	1580	
Spectral Width (RMS)	LR1 (0°C to 70°C) & IR	$\Delta\lambda_{RMS}$	-	-	4	nm
Spectral Width (-20 dB)	LR1 (-40°C to 85°C) & LR2	$\Delta\lambda_{20}$	-	-	1	
Side Mode Suppression Ratio	LR1 (-40°C to 85°C) & LR2	SMSR	30	-	-	dB
Optical Rise and Fall Time (10% to 90%)		t_r, t_f	-	2	4	ns
Optical Output Eye	compliant with Bellcore TR-NWT-000253 and ITU-T Recommendation G.957					

Receiver Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	5	52	100	Mb/s
Receiver Sensitivity (10^{-10} BER)[1]		P_{min}	- 40.0	- 42.0	-	dBm
Maximum Input Optical Power (10^{-10} BER)[1]	Dual supply	P_{max}	- 3.0	0	-	dBm
	Single supply		- 6.0	0	-	
Signal Detect Thresholds	Increasing Light Input	P_{sd+}	-	-	- 40.0	dBm
	Decreasing Light Input	P_{sd-}	- 50.0	-	-	
Signal Detect Hysteresis		-	0.5	1.5	-	dB
Wavelength of Operation		λ	1100	-	1600	nm

[1] Specified in Average Optical Input Power and measured at 52 Mb/s and 1300 nm wavelength with 2^{23}-1 PRBS.

Ordering Information

SXX - 01 - *YYY* -*T*- *Ln* - *DR*

Model
STX: Transmitter
SRX: Receiver

Package style
PFC: pigtailed with FC
PSC: pigtailed with SC
PST: pigtailed with ST
FC : FC Receptacle
ST : ST Receptacle
SC : SC Receptacle

Temperature Range
A: - 40°C to +85°C
B: 0°C to +70°C

Light Output (TX only)
HP: 0 dBm (typ.)
L0: - 3 dBm (typ.)
L1: - 5 dBm (typ.)
L2: - 8 dBm (typ.)
L3: - 11 dBm (typ.)

Distance Option (TX only)
specifies the range for Center Wavelength & Spectral Width to be compliant with SONET/SDH standard
"Blank" : Intermediate Reach
LR1 : Long Reach 1310 nm
LR2 : Long Reach 1550 nm

NOTES

1. For full compliance with OC-1 Intermediate Reach standard, the STX-01-*YYY*-A-L3 & STX-01-*YYY*-B-L3 are recommended.
2. For full compliance with OC-1 Long Reach 1310 nm standard, the STX-01-*YYY*-A-L0-LR1 & STX-01-*YYY*-B-L0-LR1 are recommended. The STX-01-*YYY*-A-L0-LR1 uses a DFB laser to satisfy the - 40°C to +85°C requirement for Center Wavelength
3. For full compliance with OC-1 Long Reach 1550 nm standard, the STX-01-*YYY*-A-L0-LR2 & STX-01-*YYY*-B-L0-LR2 are recommended. Both modules use DFB lasers. However, the STX-01-*YYY*-A-L0-LR2 module is specified only over - 25°C to +70°C temperature range.
4. The LR1 (-40°C to +85°C) and LR2 options are only available with DFB lasers and L0 or HP optical power levels.

OC-3/STM-1 Transmitter & Receiver: STX-03 & SRX-03

Transmitter Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	50	156	300	Mb/s
Average Optical Output Power (coupled into single mode fiber), 50% duty cycle	HP	P_o	- 3.0	0	+2.0	dBm
	L0		- 5.0	- 3.0	0	
	L1		- 8.0	- 5.0	- 2.0	
	L2		- 12.0	- 8.0	- 5.0	
	L3		- 15.0	- 11.0	- 8.0	
Extinction Ratio		P_{hi}/P_{lo}	10	-	-	dB
Center Wavelength	IR (Intermediate Reach)	λ_c	1261	1310	1360	nm
	LR1 (Long Reach 1310 nm)		1280	1310	1335	
	LR2 (Long Reach 1550 nm)		1480	1550	1580	
Spectral Width (RMS)	LR1 (0°C to 70°C) & IR	$\Delta\lambda_{RMS}$	-	-	4	nm
Spectral Width (-20 dB)	LR1 (-40°C to 85°C) & LR2	$\Delta\lambda_{20}$	-	-	1	
Side Mode Suppression Ratio	LR1 (-40°C to 85°C) & LR2	$SMSR$	30	-	-	dB
Optical Rise and Fall Time (10% to 90%)		t_r, t_f	-	1	2	ns
Optical Output Eye	compliant with Bellcore TR-NWT-000253 and ITU-T Recommendation G.957					

Receiver Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	50	156	200	Mb/s
Receiver Sensitivity (10^{-10} BER) [1]		P_{min}	- 35.0	- 38.0	-	dBm
Maximum Input Optical Power (10^{-10} BER) [1]	Dual supply	P_{max}	- 3.0	0	-	dBm
	Single supply		- 6.0	0	-	
Signal Detect Thresholds	Increasing Light Input	P_{sd+}	-	-	- 35.0	dBm
	Decreasing Light Input	P_{sd-}	- 45.0	-	-	
Signal Detect Hysteresis		-	0.5	1.5	-	dB
Wavelength of Operation		λ	1100	-	1600	nm

[1] Specified in Average Optical Input Power and measured at 156 Mb/s and 1300 nm wavelength with 2^{23}-1 PRBS.

Ordering Information

SXX - 03 - YYY -T- Ln - DR

Model
STX: Transmitter
SRX: Receiver

Package style
PFC: pigtailed with FC
PSC: pigtailed with SC
PST: pigtailed with ST
FC : FC Receptacle
ST : ST Receptacle
SC : SC Receptacle

Temperature Range
A: - 40°C to +85°C
B: 0°C to +70°C

Light Output (TX only)
HP: 0 dBm (typ.)
L0: - 3 dBm (typ.)
L1: - 5 dBm (typ.)
L2: - 8 dBm (typ.)
L3: - 11 dBm (typ.)

Distance Option (TX only)
specifies the range for Center Wavelength & Spectral Width to be compliant with SONET/SDH standard
"Blank" : Intermediate Reach / S-1.1
LR1 : Long Reach 1310 nm / L-1.1
LR2 : Long Reach 1550 nm / L-1.2

NOTES

1. For full compliance with OC-3/STM-1 Intermediate Reach/S-1.1 standard, the STX-03-*YYY*-*T*-L3 modules are recommended.
2. For full compliance with OC-3/STM-1 Long Reach 1310 nm/L-1.1 standard, the STX-03-*YYY*-A-L0-LR1 & STX-03-*YYY*-B-L0-LR1 are recommended. The STX-01-*YYY*-A-L0-LR1 uses a DFB laser to satisfy the Center Wavelength requirement.
3. For full compliance with OC-3/STM-1 Long Reach 1550 nm/L-1.2 standard, the STX-03-*YYY*-A-L0-LR2 & STX-03-*YYY*-B-L0-LR2 are recommended. Both modules use DFB lasers. However, the STX-03-*YYY*-A-L0-LR2 module is specified only over - 25°C to +70°C temperature range. Please consult OCP Sales for the - 40°C to +70°C pigtailed option.
4. The LR1 (-40°C to +85°C) and LR2 options are only available with DFB lasers and L0 or HP optical power levels.

OC-12/STM-4 Transmitter & Receiver: STX-12 & SRX-12

Transmitter Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	50	622	700	Mb/s
Average Optical Output Power (coupled into single mode fiber), 50% duty cycle	HP	P_o	- 3.0	0	+2.0	dBm
	L0		- 5.0	- 3.0	0	
	L1		- 8.0	- 5.0	- 2.0	
	L2		- 12.0	- 8.0	- 5.0	
	L3		- 15.0	- 11.0	- 8.0	
Extinction Ratio	SR & IR	P_{hi}/P_{lo}	8.2	-	-	dB
	LR1 & LR2		10	-	-	
Center Wavelength [1]	SR (Short Reach)	λ_c	1261	1310	1360	nm
	IR (Intermediate Reach)		1274	1310	1356	
			1293	1310	1334	
	LR1 (Long Reach 1310 nm)		1280	1310	1335	
	LR2 (Long Reach 1550 nm)		1480	1550	1580	
Spectral Width (RMS) [1]	SR (Short Reach)	$\Delta\lambda_{RMS}$	-	-	4.0	nm
	IR (Intermediate Reach)		-	-	2.5	
			-	-	4.0	
Spectral Width (-20 dB)	LR1 & LR2	$\Delta\lambda_{20}$	-	-	1.0	
Side Mode Suppression Ratio	LR1 & LR2	SMSR	30	-	-	dB
Optical Rise and Fall Time (10% to 90%)		t_r, t_f	-	0.5	1.0	ns
Optical Output Eye	compliant with Bellcore TR-NWT-000253 and ITU-T Recommendation G.957					

[1] For Intermediate Reach version, the Center Wavelength is either 1274 nm $\leq \lambda_c \leq$ 1356 nm for $\Delta\lambda_{RMS} \leq$ 2.5 nm or 1293 nm $\leq \lambda_c \leq$ 1334 nm for $\Delta\lambda_{RMS} \leq$ 4.0 nm.

Receiver Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	50	622	700	Mb/s
Receiver Sensitivity (10^{-10} BER) [1]		P_{min}	- 29.0	- 31.0	-	dBm
Maximum Input Optical Power (10^{-10} BER) [1]	Dual supply	P_{max}	- 3.0	0	-	dBm
	Single supply		- 6.0	0	-	
Signal Detect Thresholds	Increasing Light Input	P_{sd+}	-	-	- 29.0	dBm
	Decreasing Light Input	P_{sd-}	- 40.0	-	-	
Signal Detect Hysteresis		-	0.5	1.5	-	dB
Wavelength of Operation		λ	1100	-	1600	nm

[1] Specified in Average Optical Input Power and measured at 622 Mb/s and 1300 nm wavelength with 2^{23}-1 PRBS.

Ordering Information

SXX - 12 - *YYY* -*T*- *Ln* - *DR*

Model
STX: Transmitter
SRX: Receiver

Package style
PFC: pigtailed with FC
PSC: pigtailed with SC
PST: pigtailed with ST
FC : FC Receptacle
ST : ST Receptacle
SC : SC Receptacle

Temperature Range
A: - 40°C to +85°C
B: 0°C to +70°C

Light Output (TX only)
HP: 0 dBm (typ.)
L0: - 3 dBm (typ.)
L1: - 5 dBm (typ.)
L2: - 8 dBm (typ.)
L3: - 11 dBm (typ.)

Distance Option (TX only)
specifies the range for Center Wavelength & Spectral Width to be compliant with SONET/SDH standard
"Blank": Short Reach (SR)
IR :Intermediate Reach / S-4.1
LR1 : Long Reach 1310 nm / L-4.1
LR2 : Long Reach 1550 nm / L-4.2

NOTES

1. For full compliance with OC-12/STM-4 Intermediate Reach/S-4.1 standard, the STX-12-*YYY-T*-L3-IR modules are recommended.
2. For full compliance with OC-12/STM-4 Long Reach 1310 nm/L-4.1 standard, the STX-12-*YYY-T*-HP-LR1 modules are recommended. They use DFB lasers to satisfy the Center Wavelength and Spectral Width requirement.
3. For full compliance with OC-12/STM-4 Long Reach 1550 nm/L-4.2 standard, the STX-12-*YYY-T*-HP-LR2 modules are recommended. Both modules use DFB lasers. However, the STX-12-*YYY*-A-HP-LR2 module is specified only over - 25°C to +70°C temperature range. Please consult OCP Sales for the - 40°C to +70°C pigtailed option.
4. The LR1 and LR2 options are only available with DFB lasers and L0 or HP optical power levels.

OC-24 Transmitter & Receiver: STX-24 & SRX-24

Transmitter Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	50	1250	1500	Mb/s
Average Optical Output Power (coupled into single mode fiber), 50% duty cycle	HP	P_o	- 3.0	0	+2.0	dBm
	L0 [1]		- 5.0	- 3.0	0	
	L1		- 8.0	- 5.0	- 2.0	
	L2		- 12.0	- 8.0	- 5.0	
	L3		- 15.0	- 11.0	- 8.0	
Extinction Ratio	SR & IR	P_{hi}/P_{lo}	8.2	-	-	dB
	LR1 & LR2		10	-	-	
Center Wavelength [2]	SR (Short Reach) & IR (Intermediate Reach)	λ_c	1261	1310	1360	nm
	LR1 (Long Reach 1310 nm)		1280	1310	1335	
	LR2 (Long Reach 1550 nm)		1480	1550	1580	
Spectral Width (RMS) [2]	SR (Short Reach)	$\Delta\lambda_{RMS}$	-	-	4.0	nm
Spectral Width (-20 dB)	IR (Intermediate Reach)	$\Delta\lambda_{20}$	-	-	1.0	
	LR1 & LR2		-	-	1.0	
Side Mode Suppression Ratio	LR1 & LR2	$SMSR$	30	-	-	dB
Optical Rise and Fall Time (10% to 90%)		t_r, t_f	-	0.3	0.5	ns
Optical Output Eye	compliant with Bellcore TR-NWT-000253					

[1] The power specifications for the L0 version for LR2 is - 4.0 dBm min and +1 dBm max

Receiver Performance Characteristics (over Operating Case Temperature)

Parameter		Symbol	Minimum	Typical	Maximum	Units
Data Rate		B	5	1250	1500	Mb/s
Receiver Sensitivity (10^{-10} BER) [1]		P_{min}	- 22.0	- 26.0	-	dBm
Maximum Input Optical Power (10^{-10} BER) [1]	Dual supply	P_{max}	0	+2	-	dBm
	Single supply		- 5.0	0	-	
Signal Detect Thresholds	Increasing Light Input	P_{sd+}	-	-	- 22.0	dBm
	Decreasing Light Input	P_{sd-}	- 35.0	-	-	
Signal Detect Hysteresis		-	0.5	1.5	-	dB
Wavelength of Operation		λ	1100	-	1600	nm

[1] Specified in Average Optical Input Power and measured at 1250 Mb/s and 1300 nm wavelength with 2^{23}-1 PRBS.

Ordering Information

SXX - 24 - *YYY* -*T*- *Ln* - *DR*

Model
STX: Transmitter
SRX: Receiver

Package style
PFC: pigtailed with FC
PSC: pigtailed with SC
PST: pigtailed with ST
FC : FC Receptacle
ST : ST Receptacle
SC : SC Receptacle

Temperature Range
A. - 40°C to +85°C
B 0°C to +70°C

Light Output (TX only)
HP. 0 dBm (typ.)
L0: - 3 dBm (typ.)
L1: - 5 dBm (typ.)
L2: - 8 dBm (typ.)
L3: - 11 dBm (typ.)

Distance Option (TX only)
specifies the range for Center Wavelength & Spectral Width to be compliant with SONET/SDH standard
"Blank": Short Reach (SR)
IR :Intermediate Reach
LR1 : Long Reach 1310 nm
LR2 : Long Reach 1550 nm

NOTES

1. The STX-24-*YYY*-A-L2 & STX-24-*YYY*-B-L2 are fully compliant with OC-24 Short Reach standard.
2. The STX-24-*YYY*-A-L0-IR & STX-24-*YYY*-B-L0-IR are fully compliant with OC-24 Intermediate Reach standard
   The STX-24-*YYY*-A-L0-LR1 & STX-24-*YYY*-B-L0-LR1 are fully compliant with OC-24 Long Reach 1310 nm standard
   The STX 24-*YYY*-A-L0-LR2 & STX-24-*YYY*-B-L0-LR2 are fully compliant with OC-24 Long Reach 1550 nm standard
   They all use DFB lasers. In addition, the STX-24-*YYY*-A-L0-LR2 module is specified only over - 25°C to +70°C temperature range.
3. The IR option is available only with DFB lasers and L0 or HP optical power levels.
4. The LR1 and LR2 options are available only with DFB lasers and L0 or HP optical power levels.
5. The SRX-24 receiver is only specified for the Short Reach & Intermediate Reach standard. The Long Reach version is not available yet

STX / SRX

Transmitter Electrical Interface

Parameter		Symbol	Minimum	Typical	Maximum	Units
Supply Voltage [1]		$V_{CC} - V_{EE}$	4.75	5.0	5.5	V
Supply Current	receptacled-DFB	I	-	90	150	mA
	all others		-	70	130	
Input HIGH Voltage		V_{IH}	V_{CC} - 1.165	-	V_{CC} - 0.880	V
Input LOW Voltage		V_{IL}	V_{CC} - 1.810	-	V_{CC} - 1.475	V
Transmitter Disable Voltage		V_{DIS}	V_{CC} - 2.0	-	V_{CC}	V
Transmitter Enable Voltage		V_{EN}	V_{EE}	-	V_{EE} + 0.8	V
Differential Bias Monitor Voltage	at 25°C	$V_{BM,DIF}$	-	80	120	mV
	at 85°C		-	280	500	
Differential Back Facet Monitor Voltage		$V_{FM,DIF}$	20	100	200	mV

[1] For - 5V single supply, connect V_{CC} to 0V (circuit ground) and V_{EE} to - 5V
For +5V single supply, connect V_{CC} to +5V and V_{EE} to 0V (circuit ground).
CASE is always connected to circuit ground.

Receiver Electrical Interface

Parameter	Symbol	Minimum	Typical	Maximum	Units
Supply Voltage [1]	$V_{CC} - V_{EE}$	4.75	5.0	5.5	V
	V_{PD}	- 10.0	- 5.0	- 2.0	V
Supply Current	I	-	85	120	mA
Output HIGH Voltage	V_{OH}	V_{CC} - 1.06	-	V_{CC} - 0.85	V
Output LOW Voltage	V_{OL}	V_{CC} - 1.86	-	V_{CC} - 1.59	V

[1] For +5V & - 5V dual supply V_{CC} = +5V, V_{EE} = CASE = 0V (circuit ground) and V_{PD} = - 5V.
For +5V single supply : V_{CC} = +5V and V_{EE} = V_{PD} = CASE = 0V (circuit ground).
For - 5V single supply : V_{CC} = CASE = 0V (circuit ground) and V_{EE} = V_{PD} = - 5V.
CASE is always connected to circuit ground

.pplication Notes

Transmitter: When the DATA+ input is at logic HIGH and DATA- input is at logic LOW, the LD is ON; and vice versa. In single-ended applications, the unused input pin should be biased to V_{CC} - 1.29 V. The transmitter is normally enabled (i.e. when the DISABLE control input is not connected). When the DISABLE control input voltage is higher than V_{CC} - 2 V, the laser is disabled (less than -30dBm output power) independent of the input data.

Receiver: Both differential DATA+ and DATA- outputs are PECL/ECL levels requiring termination (50 ohms to V_{CC} - 2 volts or 510 ohms to V_{EE} is recommended). For optimum performance, both outputs should be terminated in the same manner, even if only one is used.

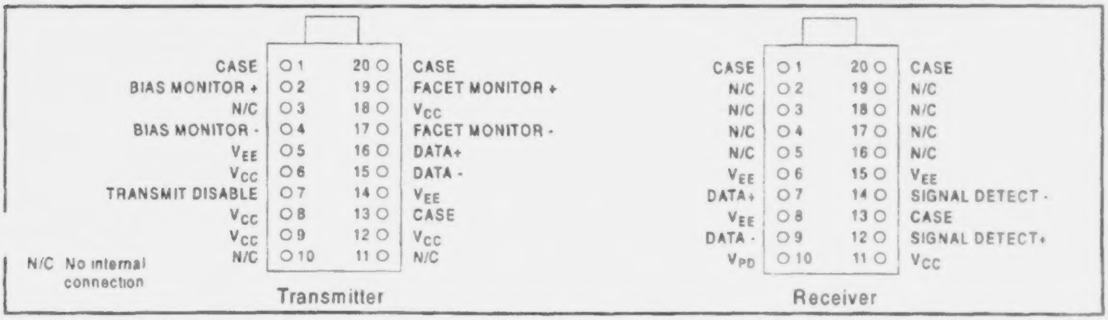
The Signal Detect circuit monitors the level of the incoming optical signal and generates a logic LOW signal when insufficient photocurrent is produced. The SIGNAL DETECT outputs are PECL/ECL level requiring termination (510 ohms to V_{EE} is recommended). If TTL interfaces for SIGNAL DETECT outputs are required, the SRX-12-L receivers can be used.

Laser Safety: All transmitters are Class I Laser products per FDA/CDRH and IEC-825 standards. They must be operated under specified operating conditions.

Optical Communication Products, Inc.
DATE OF MANUFACTURE.

MANUFACTURED IN THE USA
This product complies with
21 CFR 1040.10 and 1040.11
Meets Class I Laser Safety Requirements

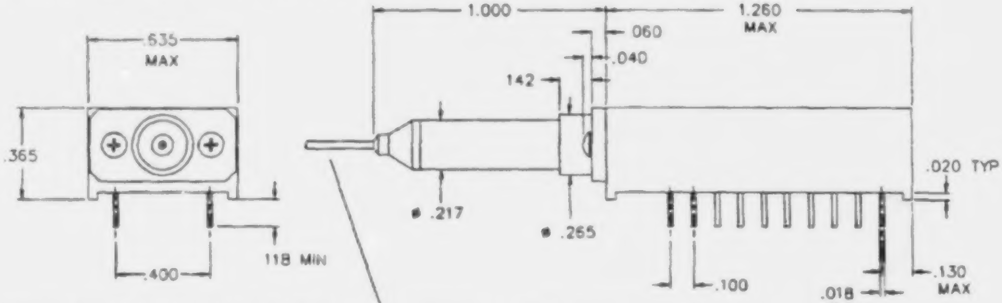
Pin Assignments (Top View)


CASE ○1 20○ CASE
BIAS MONITOR + ○2 19○ FACET MONITOR +
N/C ○3 18○ VCC
BIAS MONITOR - ○4 17○ FACET MONITOR -
VEE ○5 16○ DATA+
VCC ○6 15○ DATA -
TRANSMIT DISABLE ○7 14○ VEE
VCC ○8 13○ CASE
VCC ○9 12○ VCC
N/C ○10 11○ N/C
N/C No internal connection
Transmitter
CASE ○1 20○ CASE
N/C ○2 19○ N/C
N/C ○3 18○ N/C
N/C ○4 17○ N/C
N/C ○5 16○ N/C
VEE ○6 15○ VEE
DATA+ ○7 14○ SIGNAL DETECT -
VEE ○8 13○ CASE
DATA - ○9 12○ SIGNAL DETECT+
VPD ○10 11○ VCC
Receiver

STX / SRX

Pigtailed Transmitter Package

For Fabry-Perot laser transmitters, only the top configuration is applicable.
For DFB laser transmitters, both configurations are applicable.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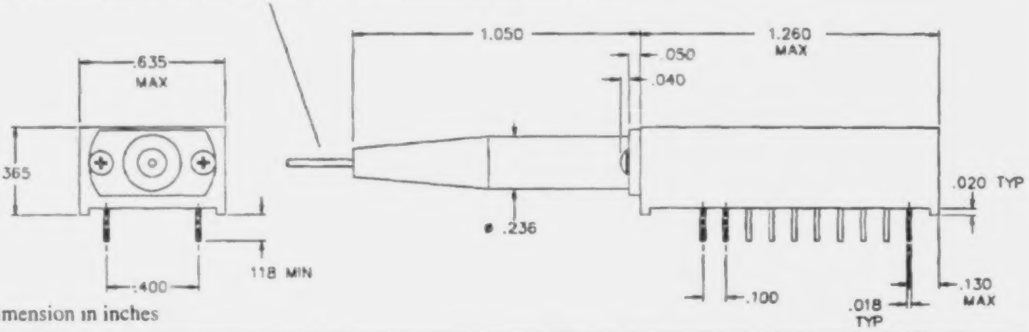
.365
.400
118 MIN
1.000
1.260 MAX
060
.040
142
ø .217
ø .265
.020 TYP
.100
.018 TYP
.130 MAX

The pigtail length from the package edge is 1.0 meter minimum, 1.1 meter typical.


.635 MAX
365
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1.050
1.260 MAX
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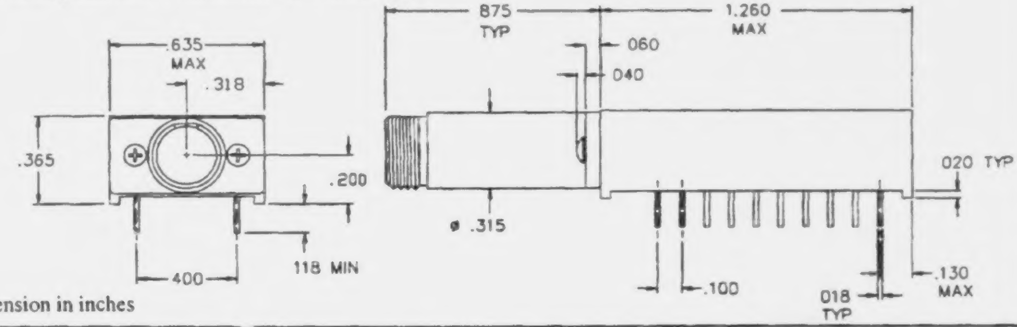
ø .236
.020 TYP
.100
.018 TYP
.130 MAX

Dimension in inches

FC Receptacled Transmitter Package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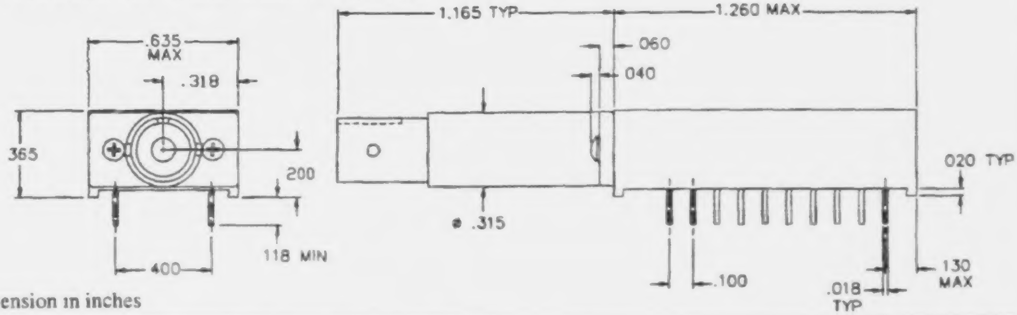
400
118 MIN
875 TYP
1.260 MAX
060
040
ø .315
020 TYP
.100
018 TYP
.130 MAX

Dimension in inches

ST Receptacled Transmitter Package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1.165 TYP
1.260 MAX
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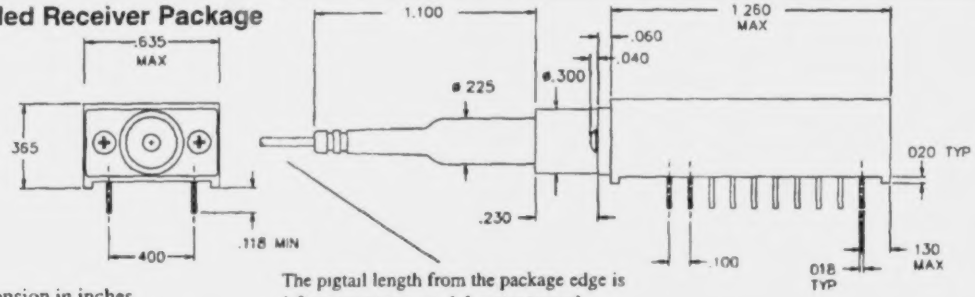
ø .315
020 TYP
.100
.018 TYP
130 MAX

Dimension in inches

STX / SRX

Pigtailed Receiver Package



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1 260
MAX
020 TYP
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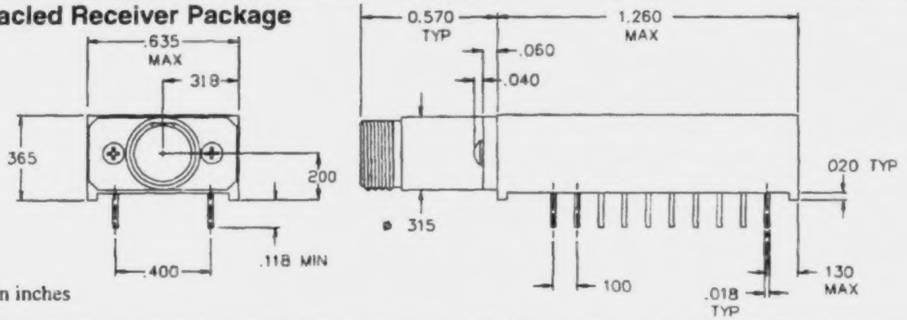
018
TYP
130
MAX

Dimension in inches

The pigtail length from the package edge is 1.0 meter minimum, 1.1 meter typical.

FC Receptacled Receiver Package



.635
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.118 MIN
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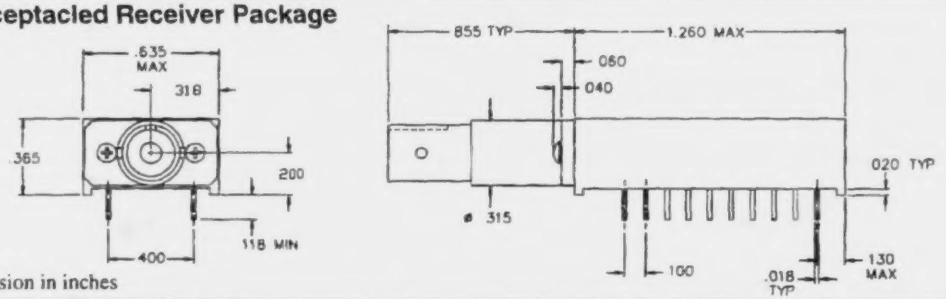
TYP
1.260
MAX
.060
.040
ø 315
020 TYP
100
.018
TYP
130
MAX

Dimension in inches

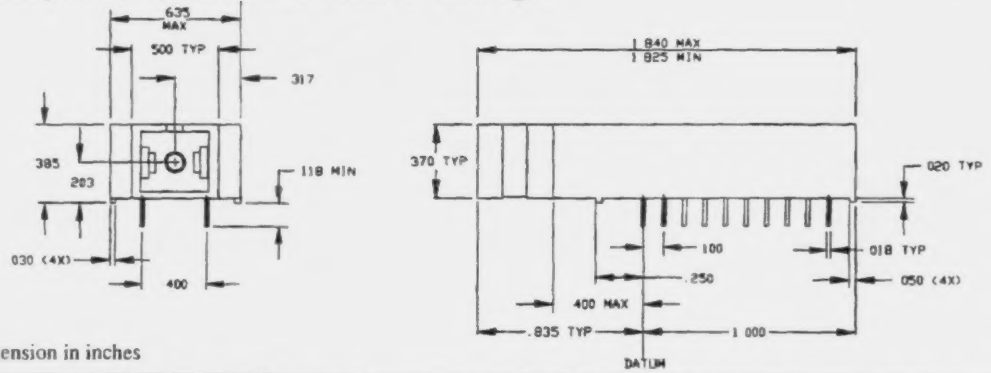
ST Receptacled Receiver Package



.635
MAX
318
365
200
400
118 MIN
855 TYP
1.260 MAX
060
040
ø 315
020 TYP
100
.018
TYP
130
MAX

Dimension in inches

SC Receptacled Transmitter & Receiver Package



635
MAX
500 TYP
317
385
203
118 MIN
030 (4X)
400
1 840 MAX
1 825 MIN
370 TYP
020 TYP
100
018 TYP
.250
050 (4X)
400 MAX
.835 TYP
1 000
DATUM

Dimension in inches

Optical Communication Products, Inc.

9736 Eton Avenue, Chatsworth, CA 91311, Tel.: 818-701-0164, FAX: 818-701-1468

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Agilent Technologies
Innovating the HP Way

1300 nm Fiber Optic Transmitter and Receiver

Technical Data

HFBR-0300 Series:
HFBR-1312T Transmitter
HFBR-2316T Receiver

Features

- **Low Cost Fiber Optic Link**
- **Signal Rates over 155 Megabaud**
- **1300 nm Wavelength**
- **Link Distances over 5 km**
- **Dual-in-line Package Panel-Mountable ST* and SC Connector Receptacles**
- **Auto-Insertable and Wave-Solderable**
- **Specified with 62.5/125 µm and 50/125 µm Fiber**
- **Compatible with HFBR-0400 Series**

Applications

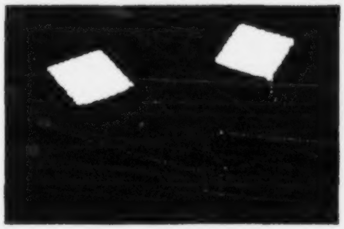
- **Desktop Links for High Speed LANs**
- **Distance Extension Links**
- **Telecom Switch Systems**
- **TAXIchip® Compatible**

Description

The HFBR-0300 Series is designed to provide the most cost-effective 1300 nm fiber optic links for a wide variety of data communication applications from low-speed distance extenders up to SONET OC-3 signal rates. Pinouts identical to Agilent HFBR-0400 Series allow designers to easily upgrade their 820 nm links for farther distance. The transmitter and receiver are compatible with two popular optical fiber sizes: 50/125 µm and 62.5/125 µm diameter. This allows flexibility in choosing a fiber size. The 1300 nm wavelength is in the lower dispersion and attenuation region of fiber, and provides longer distance capabilities than 820 nm LED technology. Typical distance capabilities are 2 km at 125 MBd and 5 km at 32 MBd.

Transmitter

The HFBR-1312T fiber optic transmitter contains a 1300 nm InGaAsP light emitting diode capable of efficiently launching optical power into 50/125 µm and 62.5/125 µm diameter fiber. Converting the interface circuit from a HFBR-14XX 820 nm transmitter to the HFBR-1312T requires only the removal of a few passive components.



Receiver

The HFBR-2316T receiver contains an InGaAs PIN photodiode and a low-noise transimpedance preamplifier that operate in the 1300 nm wavelength region. The HFBR-2316T receives an optical signal and converts it to an analog voltage. The buffered output is an emitter-follower, with frequency response from DC to typically 125 MHz. Low-cost external components can be used to convert the analog output to logic compatible signal levels for a variety of data formats and data rates. The

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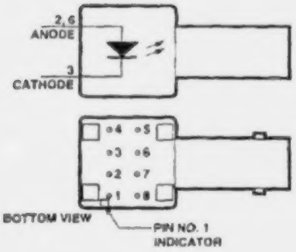
*ST is a registered trademark of AT&T Lightguide Cable Connectors

HFBR-1312T Transmitter

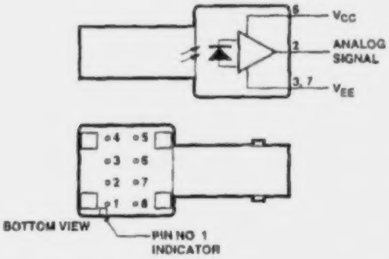

2, 6
ANODE
3
CATHODE
4
5
3
6
2
7
1
8
BOTTOM VIEW
PIN NO. 1
INDICATOR

PIN	FUNCTION
1†	N C
2	ANODE
3	CATHODE
4†	N C.
5†	N.C.
6	ANODE
7*	N C
8†	N C

* PIN 7 IS ELECTRICALLY ISOLATED FROM PINS 1, 4, 5, AND 8, BUT IS CONNECTED TO THE HEADER.

† PINS 1, 4, 5, AND 8 ARE ISOLATED FROM THE INTERNAL CIRCUITRY, BUT ARE ELECTRICALLY CONNECTED TO EACH OTHER.

HFBR-2316T Receiver

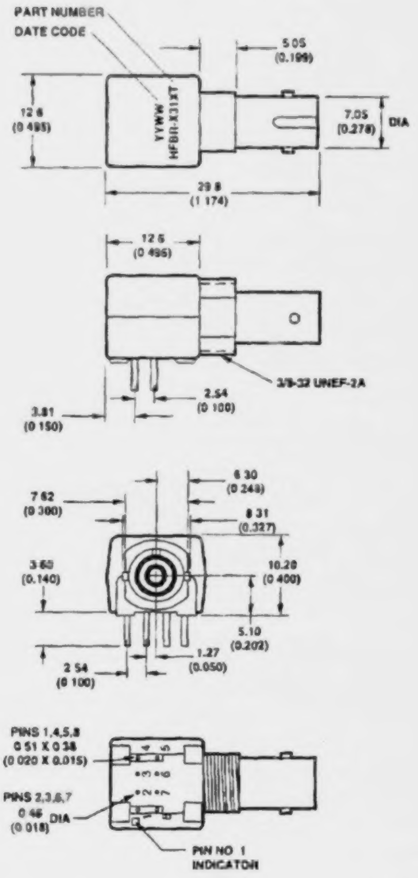

6
V_{CC}
2
ANALOG
SIGNAL
3, 7
V_{EE}
4
5
3
6
2
7
1
8
BOTTOM VIEW
PIN NO 1
INDICATOR

PIN	FUNCTION
1†	N C
2	SIGNAL
3*	V_{EE}
4†	N C
5†	N.C
6	V_{CC}
7*	V_{EE}
8†	N C

* PINS 3 AND 7 ARE ELECTRICALLY CONNECTED TO THE HEADER

† PINS 1, 4, 5, AND 8 ARE ISOLATED FROM THE INTERNAL CIRCUITRY, BUT ARE ELECTRICALLY CONNECTED TO EACH OTHER

HFBR-0300 Series
Mechanical Dimensions


PART NUMBER
DATE CODE
YYWW
HFBR-X31XT
5.05
(0.199)
12.6
(0.495)
7.05
(0.278)
DIA
29.8
(1.174)
12.6
(0.496)
3/8-32 UNEF-2A
2.54
(0.100)
3.81
(0.150)
6.30
(0.248)
7.62
(0.300)
8.31
(0.327)
3.60
(0.140)
10.20
(0.400)
5.10
(0.202)
1.27
(0.050)
2.54
(0.100)
PINS 1,4,5,8
0.51 X 0.38
(0.020 X 0.015)
PINS 2,3,6,7
0.46
(0.018)
DIA
PIN NO 1
INDICATOR

HFBR-2316T is pin compatible with HFBR-24X6 receivers and can be used to extend the distance of an existing application by substituting the HFBR-2316T for the HFBR-2416.

Package Information

HFBR-0300 Series transmitters and receivers are housed is a dual-in-line package made of high strength, heat resistant, chemically resistant, and UL V-0 flame retardant plastic. Transmitters are identified by the brown port color; receivers have black ports. The package is auto-insertable and wave solderable for high volume production applications.

Note: The "T" in the product numbers indicates a Threaded ST connector (panel mountable), for both transmitter and receiver.

Handling and Design Information

When soldering, it is advisable to leave the protective cap on the unit to keep the optics clean. Good system performance requires clean port optics and cable ferrules to avoid obstructing the optical path. Clean compressed air is often sufficient to remove particles of dirt; methanol on a cotton swab also works well.

Panel Mounting Hardware

The HFBR-4411 kit consists of 100 nuts and 100 washers with dimensions as shown in Figure 1. These kits are available from Agilent or any authorized distributor. Any standard size nut and washer will work, provided the total thickness of the wall, nut, and washer does not exceed 0.2 inch (5.1mm).

When preparing the chassis wall for panel mounting, use the mounting template in Figure 2. When tightening the nut, torque should not exceed 0.8 N-m (8.0 in-lb).

Recommended Chemicals for Cleaning/Degreasing HFBR-0300 Products

Alcohols (methyl, isopropyl, isobutyl)
Aliphatics (hexane, heptane)
Other (soap solution, naphtha)

Do not use partially halogenated hydrocarbons (such as 1.1.1 trichloroethane), ketones (such as MEK), acetone, chloroform, ethyl acetate, methylene dichloride, phenol, methylene chloride, or N-methylpyrolldone. Also, Agilent does not recommend the use of cleaners that use halogenated hydrocarbons because of their potential environmental harm.

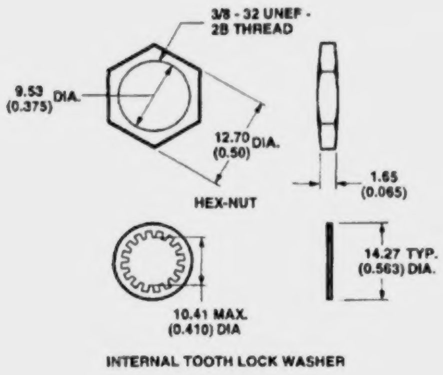


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Figure 1. HFBR-4411 Mechanical Dimensions.

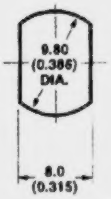


Figure 2. Recommended Cut-out for Panel Mounting.

HFBR-1312T Transmitter Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit	Reference
Storage Temperature	T_S	-55	85	°C	
Operating Temperature	T_A	-40	85	°C	
Lead Soldering Cycle Temperature			260	°C	Note 8
Lead Soldering Cycle Time			10	sec	
Forward Input Current DC	I_{FDC}		100	mA	
Reverse Input Voltage	V_R		1	V	

CAUTION. The small junction sizes inherent to the design of this bipolar component increase the component's susceptibility to damage from electrostatic discharge (ESD) It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation which may be induced by ESD

HFBR-1312T Transmitter Electrical/Optical Characteristics

0 to 70°C unless otherwise specified

Parameter	Symbol	Min.	Typ.[1]	Max.	Unit	Condition	Ref.
Forward Voltage	V_F	1.1	1.4	1.7	V	I_F = 75 mA	Fig. 1
			1.5			I_F = 100 mA	
Forward Voltage Temperature Coefficient	$\Delta V_F/\Delta T$		-1.5		mV/°C	I_F = 75 - 100 mA	
Reverse Input Voltage	V_R	1	4		V	I_R = 100 μA	
Center Emission Wavelength	λ_C	1270	1300	1370	nm		
Full Width Half Maximum	FWHM		130	185	nm		
Diode Capacitance	C_T		16		pF	V_F = 0 V, f = 1 MHz	
Optical Power Temperature Coefficient	$\Delta P_T/\Delta T$		-0.03		dB/°C	I_F = 75 - 100 mA DC	
Thermal Resistance	Θ_{JA}		260		°C/W		Note 2

HFBR-1312T Transmitter Output Optical Power and Dynamic Characteristics

						Condition		
Parameter	Symbol	Min.	Typ.[1]	Max.	Unit	T_A	$I_{F, peak}$	Ref.
Peak Power 62.5/125 μm NA = 0.275	P_{T62}	-16.0	-14.0	-12.5	dBm	25°C	75 mA	Notes 3, 4, 5
		-17.5		-11.5		0-70°C	75 mA	
		-15.5	-13.5	-12.0		25°C	100 mA	Fig. 2
		-17.0		-11.0		0-70°C	100 mA	
Peak Power 50/125 μm NA = 0.20	P_{T50}	-19.5	-17.0	-14.5	dBm	25°C	75 mA	Notes 3, 4, 5
		-21.0		-13.5		0-70°C	75 mA	
		-19.0	-16.5	-14.0		25°C	100 mA	Fig. 2
		-20.5		-13.0		0-70°C	100 mA	
Optical Overshoot	OS		5	10	%	0-70°C	75 mA	Note 6 Fig. 3
Rise Time	t_r		1.8	4.0	ns	0-70°C	75 mA	Note 7 Fig. 3
Fall Time	t_f		2.2	4.0	ns	0-70°C	75 mA	Note 7 Fig. 3

Notes:

1. Typical data are at $T_A = 25°C$.
2. Thermal resistance is measured with the transmitter coupled to a connector assembly and mounted on a printed circuit board, $\Theta_{JC} < \Theta_{JA}$.
3. Optical power is measured with a large area detector at the end of 1 meter of mode stripped cable, with an ST* precision ceramic ferrule (MIL-STD-83522/13), which approximates a standard test connector. Average power measurements are made at 12.5 MHz with a 50% duty cycle drive current of 0 to $I_{F,peak}$; $I_{F,average} = I_{F,peak}/2$. Peak optical power is 3 dB higher than average optical power.
4. When changing from µW to dBm, the optical power is referenced to 1 mW (1000 µW).
   Optical power P(dBm) = 10*log[P(µW)/1000µW]
5. Fiber NA is measured at the end of 2 meters of mode stripped fiber using the far-field pattern. NA is defined as the sine of the half angle, determined at 5% of the peak intensity point. When using other manufacturer's fiber cable, results will vary due to differing NA values and test methods
6. Overshoot is measured as a percentage of the peak amplitude of the optical waveform to the 100% amplitude level. The 100% amplitude level is determined at the end of a 40 ns pulse, 50% duty cycle. This will ensure that ringing and other noise sources have been eliminated
7. Optical rise and fall times are measured from 10% to 90% with 62.5/125 µm fiber. LED response time with recommended test circuit (Figure 3) at 25 MHz, 50% duty cycle
8. 2.0 mm from where leads enter case

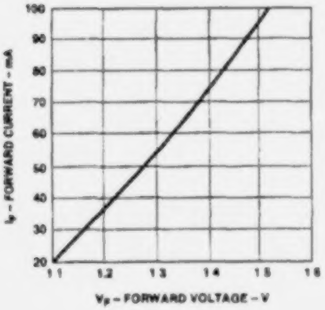


Figure 1. Typical Forward Voltage and Current Characteristics.

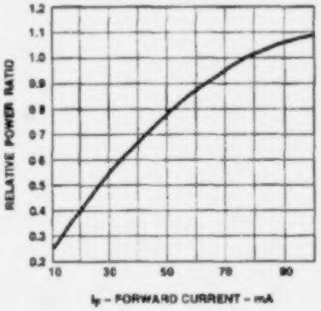


Figure 2. Normalized Transmitter Output Power vs. Forward Current.

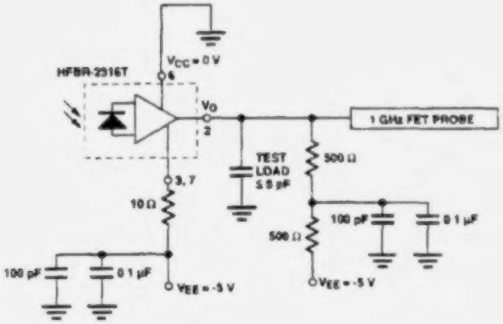


Figure 3. Recommended ~~Transmitter~~ Drive and Test Circuit.

[illegible]

HFBR-2316T Receiver Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit	Reference
Storage Temperature	T_S	-55	85	°C	
Operating Temperature	T_A	-40	+85	°C	
Lead Soldering Temperature			260	°C	Note 1
Cycle Time			10	s	
Signal Pin Voltage	V_O	-0.5	V_{CC}	V	
Supply Voltage	$V_{CC} - V_{EE}$	-0.5	6.0	V	Note 2
Output Current	I_O		25	mA	

CAUTION: The small junction sizes inherent to the design of this bipolar component increase the component's susceptibility to damage from electrostatic discharge (ESD). It is advised that normal static precautions be taken in handling and assembly of this component to prevent damage and/or degradation which may be induced by ESD

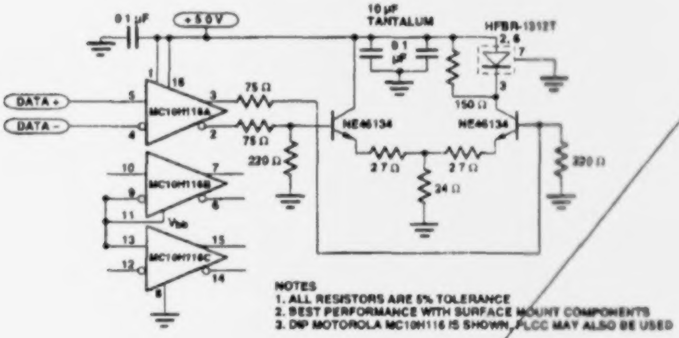
HFBR-2316T Receiver Electrical/Optical and Dynamic Characteristics

0 to 70°C; 4.75 V < $V_{CC} - V_{EE}$ < 5.25 V; power supply must be filtered (see note 2).

Parameter	Symbol	Min.	Typ.[3]	Max.	Unit	Condition	Ref.
Responsitivity	R_P	6.5	13	19	mV/μW	λ_p = 1300 nm, 50 MHz	Note 4 Fig. 1, 5
RMS Output Noise Voltage	V_{NO}		0.4	0.59	mV_{RMS}	100 MHz bandwidth, $P_R = 0$ μW	Note 5 Fig. 2
				1.0	mV_{RMS}	Unfiltered Bandwidth $P_R = 0$ μW	
Equivalent Optical Noise Input Power (RMS)	$P_{N,RMS}$		-45	-41.5	dBm	@ 100 MHz, $P_R = 0$ μW	Note 5
			0.032	0.071	μW		
Peak Input Optical Power	P_R			-11.0	dBm	50 MHz, 1 ns PWD	Note 6 Fig 3
				80	μW		
Output Resistance	R_O		30		Ohm	f = 50 MHz	
DC Output Voltage	$V_{O,DC}$	0.8	1.8	2.6	V	$V_{CC} = 5$ V, $V_{EE} = 0$ V $P_R = 0$ μW	
Supply Current	I_{CC}		9	15	mA	$R_{LOAD} = \infty$	
Electrical Bandwidth	BW_E	75	125		MHz	-3 dB electrical	Note 7
Bandwidth * Rise Time Product			0.41		Hz *s		
Electrical Rise, Fall Times, 10-90%	t_r, t_f		3.3	5.3	ns	P_R = -15 dBm peak, @ 50 MHz	Note 8 Fig. 4
Pulse-Width Distortion	PWD		0.4	1.0	ns	P_R = -11 dBm, peak	Note 6,9 Fig. 3
Overshoot			2		%	P_R = -15 dBm, peak	Note 10

Notes:

1. 2.0 mm from where leads enter case
2. The signal output is referred to V_{CC}, and does not reject noise from the V_{CC} power supply. Consequently, the V_{CC} power supply must be filtered. The recommended power supply is +5 V on V_{CC} for typical usage with +5 V ECL logic. A -5 V power supply on V_{EE} is used for test purposes to minimize power supply noise.
3. Typical specifications are for operation at $T_A = 25°C$ and $V_{CC} = +5\ V_{DC}$
4. The test circuit layout should be in accordance with good high frequency circuit design techniques
5. Measured with a 9-pole "brick wall" low-pass filter [Mini-Circuits™, BLP-100*] with -3 dB bandwidth of 100 MHz.
6. -11 0 dBm is the maximum peak input optical power for which pulse-width distortion is less than 1 ns.
7. Electrical bandwidth is the frequency where the responsivity is -3 dB (electrical) below the responsivity measured at 50 MHz
8. The specified rise and fall times are referenced to a fast square wave optical source. Rise and fall times measured using an LED optical source with a 2.0 ns rise and fall time (such as the HFBR-1312T) will be approximately 0.6 ns longer than the specified rise and fall times E g : measured $t_{r,f} \simeq [(\text{specified } t_{r,f})^2 + (\text{test source optical } t_{r,f})^2]^{1/2}$.
9. 10 ns pulse width, 50% duty cycle, at the 50% amplitude point of the waveform
10. Percent overshoot is defined as: $((V_{PK} - V_{100\%})/V_{100\%}) \times 100\%$. The overshoot is typically 2% with an input optical rise time ≤ 1.5 ns.
11. The bandwidth*risetime product is typically 0 41 because the HFBR-2316T has a second-order bandwidth limiting characteristic.



NOTES
1. ALL RESISTORS ARE 5% TOLERANCE
2. BEST PERFORMANCE WITH SURFACE MOUNT COMPONENTS
3. DIP MOTOROLA MC10H116 IS SHOWN, PLCC MAY ALSO BE USED

Figure 1. ~~HFBR-2316T~~ Receiver Test Circuit.

HFBR 1312T + [illegible]

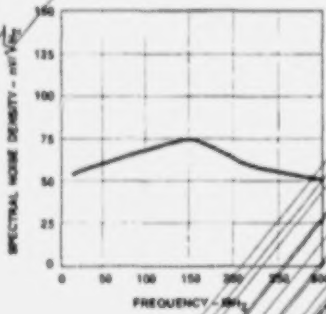


Figure 2. Typical Output Spectral Noise Density vs. Frequency.

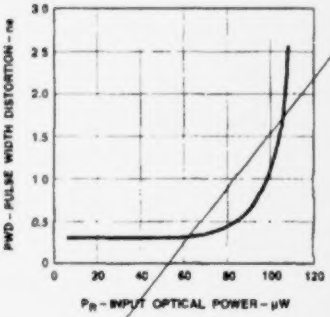


Figure 3. Typical Pulse Width Distortion vs. Peak Input Power.

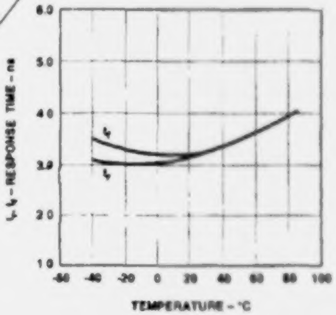


Figure 4. Typical Rise and Fall Times vs. Temperature.

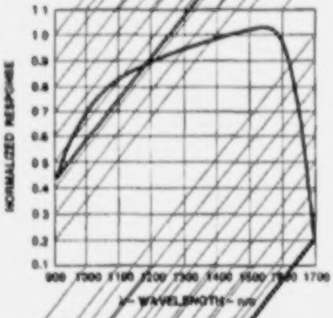


Figure 5. Normalized Receiver Spectral Response.

*Mini-Circuits Division of Components Corporation

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Innovating the HP Way

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APPLICATION NOTE

AN 107C

APRIL 1999

CARE AND FEEDING OF FIBER OPTIC CONNECTORS

BACKGROUND

Optical fiber connectors have traditionally been the biggest concern in using fiber optic systems. While connectors were once unwieldy and difficult to use, connector manufacturers have standardized and simplified connectors greatly. This increasing user-friendliness has contributed to the increase in the use of fiber optic systems; it has also taken the emphasis off the proper care and handling of optical connectors. Force has observed a number of fiber optic systems perform poorly because the optical connector was mishandled or dirty. Improper test techniques have contributed to the belief that the system itself was not working when, in fact, this was not so. It is clear, in this case, that some information on optical connectors could help system users improve their system performance levels.

While Force customers will more than likely be using connectors already installed on the optical fiber, the proper use of connectors is a process rather than a single event. Therefore, this application note covers connector basics including the parts of a fiber optic connector, interconnection loss measurements, installing fiber optic connectors, and the cleaning and handling of installed connectors.

OPTICAL CONNECTOR BASICS

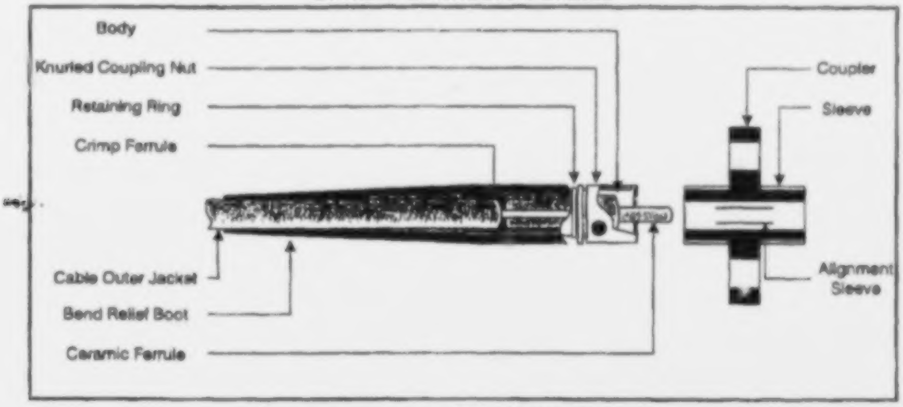

Figure 1 - Parts of a Fiber Optic Connector

Fiber-to-fiber interconnection can consist of a splice, a permanent connection, or a connector, which differs from the splice in its ability to be disconnected and reconnected. Fiber optic connector types are as various as the applications for which they were developed. Different connector types have different characteristics, different advantages and disadvantages, and different performance parameters. But all connectors have the same four basic components.

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1. The Ferrule: The fiber is mounted in a long, thin cylinder, the ferrule, which acts as a fiber alignment mechanism. The ferrule is bored through the center at a diameter that is slightly larger than the diameter of the fiber cladding. The end of the fiber is located at the end of the ferrule. Ferrules are typically made of metal or ceramic, but they may also be constructed of plastic.
2. The Connector Body: Also called the connector housing, the connector body holds the ferrule. It is usually constructed of metal or plastic and includes one or more assembled pieces which hold the fiber in place. The details of these connector body assemblies vary among connectors, but bonding and/or crimping is commonly used to attach strength members and cable jackets to the connector body. The ferrule extends past the connector body to slip into the coupling device.
3. The Cable: The cable is attached to the connector body. It acts as the point of entry for the fiber. Typically, a strain-relief boot is added over the junction between the cable and the connector body, providing extra strength to the junction.
4. The Coupling Device: Most fiber optic connectors do not use the male-female configuration common to electronic connectors. Instead, a coupling device such as an alignment sleeve is used to mate the connectors. Similar devices may be installed in fiber optic transmitters and receivers to allow these devices to be mated via a connector. These devices are also known as feed-through bulkhead adapters.

Table 1 illustrates some types of optical connectors and lists some specifications. Each connector type has strong points. For example, ST connectors are a good choice for easy field installations; the FC connector has a floating ferrule that provides good mechanical isolation; the SC connector offers excellent packing density, and its push-pull design resists fiber end face contact-damage during unmating and remating cycles. The D4 connector offers performance similar to the FC without the floating ferrule.

Table I - Types of Optical Connectors

Connector	Insertion Loss	Repeatibility	Fiber Type	Applications
Biconic 	0.60-1.00 dB	0.20 dB	SM, MM	Telecommunications
D4 	0.20-0.50 dB	0.20 dB	SM, MM	Telecommunications
EC/RACE 	0.10-0.30 dB	0.10 dB	SM	High-speed Datacom
ESCON 	0.20-0.70 dB	0.20 dB	MM	Fiber Optic Networks
FC 	0.50-1.00 dB	0.20 dB	SM, MM	Datacom, Telecommunications
FDDI 	0.20-0.70 dB	0.20 dB	SM, MM	Fiber Optic Networks
HMS-10 	0.10-0.30 dB	0.10 dB	SM	Test Equipment
LC 	0.15 dB (SM) 0.10 dB (MM)	0.2 dB	SM, MM	High Density Interconnection
MT Array 	0.30-1.00 dB	0.25dB	SM,MM	High Density Interconnection
SC 	0.20-0.45 dB	0.10 dB	SM, MM	Telecommunications
SC Duplex 	0.20-0.45 dB	0.10 dB	SM, MM	Datacom
SMA 	0.40-0.80 dB	0.30 dB	MM	Military
ST 	Typ 0.40 dB (SM) Typ 0.50 dB (MM)	Typ 0.40 dB (SM) Typ 0.20 dB (MM)	SM, MM	Inter-/Intra-Building, Security, Navy

INTERCONNECTION LOSS MEASUREMENTS

The ideal interconnection of one fiber to another would have two fibers that are optically and physically identical held by a connector or splice that squarely aligns them on their center axes. However, in the real world, system loss due to fiber interconnection is a factor. Insertion loss is the primary consideration for connector performance. There are three types of insertion loss: fiber-related loss, connector-related loss, and system factors that contribute to loss. Because of the discrepancy between insertion-loss testing and connector performance, users must understand the test methods used to measure insertion loss. The best test results are obtained when lengths of fibers are attached to the source and detector as permanent parts of the test setup. This avoids variations in results that are caused by source and detector interconnection losses from test to test.

MEASUREMENT SYSTEM COMPONENTS

There are several components required to test interconnection losses.

1. Light Source: Light sources include lasers, LED's, broadband sources, or monochromators.
    a. Lasers and light-emitting diodes (LED's) are widely used as sources. Important characteristics include output power, speed, output pattern or numerical aperture (NA), spectral width, fiber-type compatibility, ease of use, lifetime, and cost.

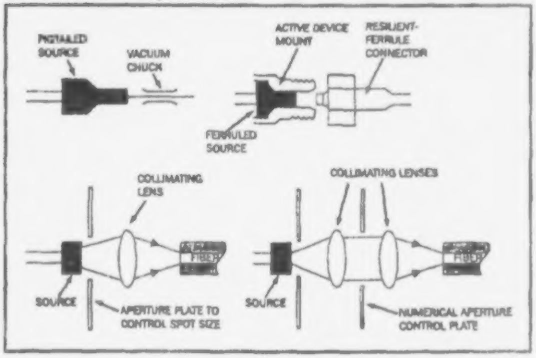

Figure 2 - Methods of Interfacing a Source to a Fiber
(Courtesy of AMP, Incorporated.)

Table 2 - LED and Laser Characteristics

CHARACTERISTIC	LED's	LASERS
Output Power	Lower (20-100 µW)	Higher (100-400 µW)
Speed	Slower	Faster
Output Pattern	Higher	Lower
Spectral Width	Wider (40-190nm FWHM)	Narrower (1-10 nm FWHM)
Fiber Type	Multimode Only	SM or MM
Ease of Use	Easier	Harder
Lifetime	Longer	Long
Cost	Low ($5-$300)	High ($100-$10,000)

    b. Broadband Source: Once popular but now seldom used, typical incandescent sources include quartz, halogen, or xenon arc lamps with interference filters. If possible, the filter should have a bandpass that approximates the output of the source to be used in the proposed system to better account for wavelength-dependent fiber characteristics such as NA, attenuation, and dispersion.
    c. Monochromator: This device isolates narrow portions of light by dispersing light into its component wavelengths. Most commercial monochromators exhibit very low energy on the output side, and they select a very narrow bandwidth.
2. Mode Scramblers: Mode scramblers mix light to excite every possible mode of transmission within the fiber. The easiest to make is a 15-cm tube at least 7 cm in diameter filled with 1-mm lead shot through which the bare fiber is passed. Another type uses a row of one-eighth inch diameter brass pins through which the fiber is zigzagged. The resulting bends in either type cause mode coupling that fills the fiber. A more complex scrambler is a butt-welded (fusion-spliced) length of alternating graded-index, step-index, graded index fibers. The step-index fiber generally has a length of one meter. The discontinuities that result mix the light; however, butt-welded scramblers are difficult to fabricate and are weak, exhibiting less than 20% of the original fiber's mechanical strength.

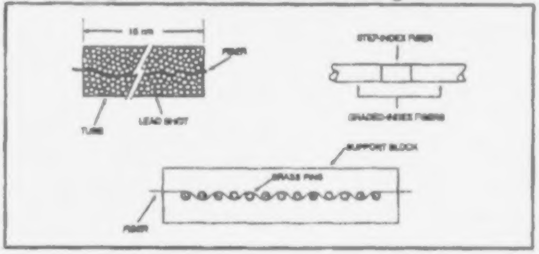

Figure 3 - Mode Scramblers
(Courtesy of AMP, Incorporated)

3. Core Mode Filter: Mandrel wrap core mode filters allow high-order mode signals from the core to be removed. High-order modes travelling through several hundred meters of fiber leak into the cladding and are lost. This results in an exit numerical aperture less than the material NA of the fiber. A fiber that has reached modal equilibrium, along with the reduced NA, is said to exhibit long-launch conditions. Rather than testing connector loss over several hundred meters of fiber, core mode filters simulate this distance. The standard recommended core mode filter for smaller fibers is 12.5-mm diameter mandrel around which the fiber is wrapped five times under zero tensions. The mandrel wrap reduces the exit NA to about 50% of the fiber's material NA. The mandrel wrap also reduces the light-emitting area of the core of a graded-index fiber by about 50%. This reduction in the emitting area affects the performance of a connector or a splice during loss measurements.

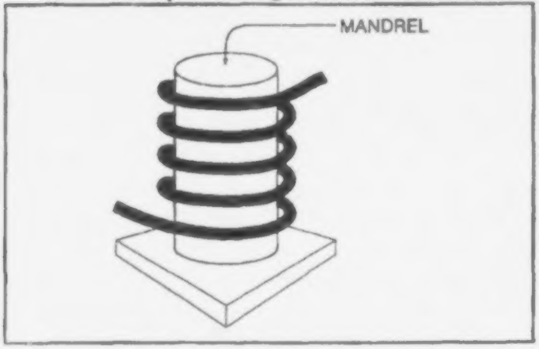

Figure 4 - Mandrel Wrap Core Mode Filter
(Courtesy of AMP, Incorporated.)

4. Cladding Mode Stripper. The use of the mandrel wrap described above scrambles the modes or strips the high-order modes. This stripped light has nowhere to go except the cladding. In short fiber runs or in setups where the mandrel wrap occurs at the end of the fiber, this light deflected to the cladding can be substantial. It is necessary to strip the cladding modes with a device known as a cladding mode stripper. This device incorporates a fiber, stripped of its cladding buffer, and covered in Corona Dope (available from TV repair suppliers) or some other liquid with a refractive index higher than the cladding. Corona Dope has advantages: it is low-cost, it has a high refractive index, and the coating is black. Figure 5 illustrates a cladding mode stripper.

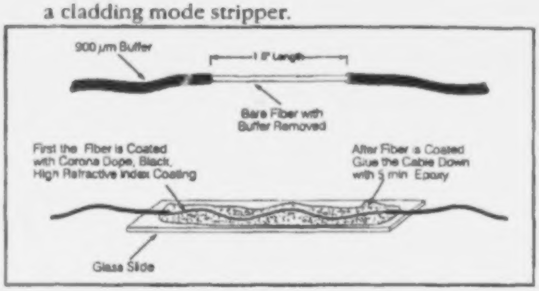
900 μm Buffer
Bare Fiber with Buffer Removed
First the Fiber is Coated with Corona Dope, Black, High Refractive Index Coating
After Fiber is Coated Glue the Cable Down with 5 min Epoxy
Glass Slide

Figure 5 - Cladding Mode Stripper

5. Detector System: Optical multimeters, also called optical power meters, read optical power levels. The meter is completely electronic with sensors that plug into the unit. Different sensors are available for use at different power levels and operating wavelengths. Adapters permit bare fibers or a variety of popular connectors to be connected to a sensor. Some multimeters include the Photodyne, Incorporated Models 22XL and 22XLA, the SOAR Corporation Model 1800 series, and Hewlett-Packard's 3478A Multimeter. A drawback of the multimeter is that in many applications both ends of the fiber must be available. An optical time-domain reflectometer allows testing when only one end of the fiber is available. This device relies on the backscattering of light that occurs in an optical fiber for detection.

INSERTION LOSS TEST

Insertion loss tests will reduce the influence of fiber-related losses. A general test should be reproducible and provide applicable results. Most tests measure the output power (P_1) of a length of fiber. The fiber is then cut in the middle and terminated with a connector or splice. The output power (P_2) is measured again. Insertion loss is given by:

$$\text{Loss (dB)} = 10 \cdot \log_{10}\left(\frac{P_1}{P_2}\right)$$

The length of fiber must be broken perfectly in the middle to produce an identical fiber on each side of the splice. This method purposely eliminates fiber-induced losses in order to evaluate connector performance independently of fiber-related variations. Three sets of launch conditions are of interest.

1. Short-launch, short-receive: Represented by short fibers with no mandrel wrap on the transmitting or receiving ends. Short-launch, short-receive con-

ditions exhibit losses that increase with the slightest mechanical offset of the connection. Lateral misalignment is a critical parameter under these conditions.

2. Long-launch, short-receive. A mandrel wrap is on the transmitting end but not on the receiving end. This condition reduces the exit numerical aperture (NA) of the transmitting fiber, and end-separation losses are smaller. Since all of the receiving core can be used, greater separation of the fibers can be tolerated.
3. Long-launch, long-receive. This condition is created by using a mandrel wrap at both the transmit and receive end and shows greater sensitivity to lateral misalignment than the other two conditions. Because the effective core area of both fibers is reduced, any offset increases loss more significantly.

The insertion loss test assumed that two pieces of identical fiber were used. However, if two different types of fibers are connected, then NA mismatch loss and diameter mismatch loss must be accounted for.

NA MISMATCH LOSS TEST

NA mismatch loss occurs when the numerical aperture of the transmitting fiber (t) is larger than that of the receiving fiber (r). NA mismatch loss is illustrated in Figure 6.

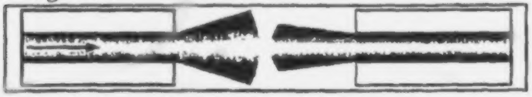

Figure 6 - NA-Mismatch

The calculated loss for numerical aperture mismatch is approximated by:

$$\mathrm{Loss}_{NA} = 10 \bullet \log_{10}\left(\frac{NA_r}{\mathrm{NA}_t}\right)^2$$

CORE/CLADDING DIAMETER MISMATCH TESTS

As illustrated in Figure 7, core diameter mismatch occurs when the core diameter of the transmitting fiber (t) is larger than the core diameter of the fiber at the receiving end (r). Cladding diameter mismatch is similar to core diameter mismatch loss except the cladding of the transmitting fiber differs in diameter from the cladding of the receiving fiber. Either mismatch prevents the cores from aligning.

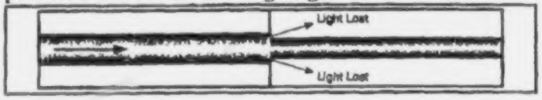

Figure 7 - Core-Diameter Mismatch

Both types of diameter mismatch loss are approximated by:

$$\mathrm{Loss}_{dia} = 10 \bullet \log_{10}\left(\frac{dia_r}{dia_t}\right)^2$$

This equation is only accurate if all of the modes in the fiber are excited. When only low-order modes are excited, the loss is greatly reduced and may not be present at all.

ALIGNMENT LOSS TESTS

Concentricity, also known as eccentricity, occurs because the core may not be perfectly centered in the cladding. Ellipticity or ovality describes the fact that the core or cladding may be elliptical rather than circular. The alignment of the two elliptical cores will vary depending on how the fibers are brought together. These forms of connector loss are illustrated in Figure 8.

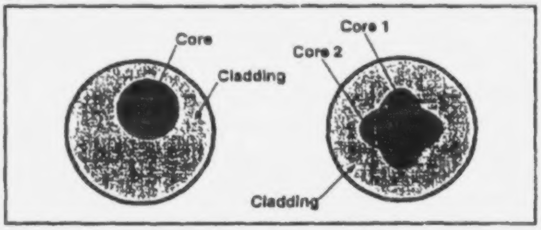

Figure 8 - Concentricity and Ellipticity

Connector-related loss can also result from the mechanical misalignment of the optical fiber cores. There are several types of misalignment loss: lateral displacement, angular misalignment, and end separation.

A connector should align the fibers on their center axes, but when one fiber's axis does not coincide with the other fiber's axis, lateral displacement occurs. A displacement of only 10% of the core axis diameter results in a loss of about 0.5 dB. The ends of mated fibers should be perpendicular to the fibers' axes and to each other. Failure to be perpendicular is called angular misalignment.

FRESNEL REFLECTION LOSS

Some connectors hold the two fibers slightly apart to prevent the fibers from rubbing against each other and damaging their end polishes. Fresnel reflection loss or end separation loss is caused by the difference in the refractive indices of the two fibers and the air that fills the gap between the two fibers. Some connector manufacturers believe the use of index-matching gel in the gap reduces Fresnel reflection loss, but others do not recommend using index-matching gel. This gap may collect small flecks of abrasive contaminates that will damage the end finishes, and the addition of index-matching gel could compound this contamination.

In a single-mode interconnection with a flat end finish, Fresnel reflection loss can be as much as -11 dB, a level sufficient to disrupt the operation of most lasers. This loss can be reduced by rounding the fiber end of one fiber during polishing (called a PC or physical contact finish). While it would seem practical to use a flat finish and butt the ends, getting two perfectly smooth, flat finishes is nearly impossible. With a rounded finish, fibers always touch on a high point near the light-carrying fiber core. (See Figure 9.)

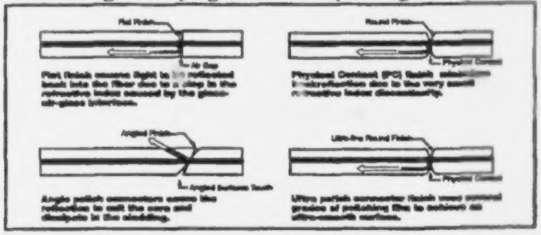

Figure 9 - Fiber End Face Finishes

SYSTEM RELATED LOSSES

System-related factors in connector loss involve the launch and receive conditions. These conditions result from the mode distribution in the fibers. The performance of the connector depends on modal conditions and the connector's position in the system. Four different conditions exist:

1. Short launch, short receive.
2. Short launch, long receive.
3. Long launch, short receive.
4. Long launch, long receive.

These launch conditions must be controlled in order to provide repeatable measurements. Long-launch conditions are generally preferred. Long-launch or receive conditions mean that equilibrium mode distribution (EMD) exists in the fiber. The Electronic Industry Association (EIA) recommends a 70/70 launch: 70% of the fiber core diameter and 70% of the fiber NA should be filled. This recommendation corresponds to the EMD in a graded-index fiber. EMD can be reached three ways: by the optical approach, filtering, or long fiber length. In general, connector losses under long-launch conditions range from 0.4-0.5 dB. Under short-launch conditions, losses are in the 1.3-1.4 dB range.

INSTALLING FIBER OPTIC CONNECTORS

The method for attaching fiber optic connectors to optical fibers varies among connector types. While not intended to be a definitive guide, the following steps are given as a reference for the basics of optical fiber interconnection.

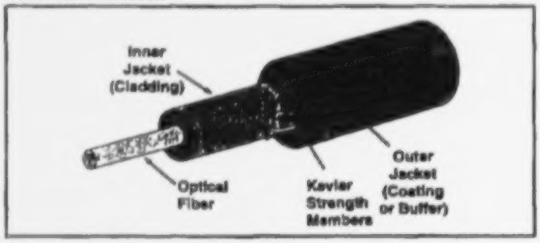

Figure 10 - Optical Fiber Construction

1. Cut the cable one inch longer than the required finished length.
2. Carefully strip the outer jacket of the fiber with "no nick" fiber strippers. Cut the exposed strength members, and remove the fiber coating. The fiber coating may be removed two ways: by soaking the fiber for two minutes in paint thinner and wiping the fiber clean with a soft, lint-free cloth, or by carefully stripping the fiber with fiber stripper. Be sure to use strippers made specifically for use with fiber rather than metal wire strippers as damage can occur, weakening the fiber. (See Figure 10.)
3. Thoroughly clean the bared fiber with isopropyl alcohol poured onto a soft, lint-free cloth such as Kimwipes®. NEVER clean the fiber with a dry tissue. Note: Use only industrial grade 99% pure isopropyl alcohol. Commercially available isopropyl alcohol is for medicinal use and is diluted with water and a light mineral oil. Industrial grade isopropyl alcohol should be used exclusively.
4. The connector may be connected by applying

epoxy or by crimping. If using epoxy, fill the connector with enough epoxy to allow a small bead of epoxy to form at the tip of the connector. Insert the clean, stripped fiber into the connector. Cure the epoxy according to the instructions provided by the epoxy manufacturer.

5. Anchor the cable strength members to the connector body. This prevents direct stress on the fiber. Slide the back end of the connector into place (where applicable).
6. Prepare the fiber face to achieve a good optical finish by cleaving and polishing the fiber end. Before connection is made, the end of each fiber must have a smooth finish that is free of defects such as hackles, lips, and fractures. These defects, as well as other impurities and dirt change the geometrical propagation patterns of light and cause scattering.

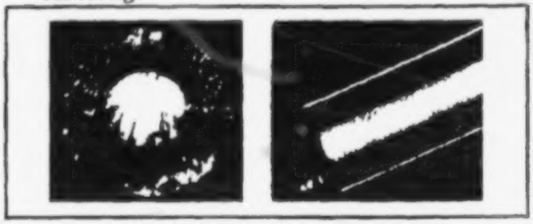

Figure 11 - Fiber End Face Defects: Hackle (left), Lip (right)
(Courtesy of AMP, Incorporated.)

CLEAVING

Cleaving involves cutting the fiber end flush with the end of the ferrule. Cleaving, also called the scribe-and-break method of fiber end face preparation, takes some skill to achieve optimum results. Properly done, the cleave produces a perpendicular, mirror-like finish. Incorrect cleaving will result in lips and hackles as seen in Figure 11. While cleaving may be done by hand, a cleaver tool, available from such manufacturers as Fujikura, allows for a more consistent finish and reduces the overall skill required. The steps listed below outline one procedure for producing good, consistent cleaves such as the one shown in Figure 12.

1. Place the blade of the cleaver tool at the tip of the ferrule.
2. Gently score the fiber across the cladding region in one direction. If the scoring is not done lightly, the fiber may break, making it necessary to reterminate the fiber.
3. Pull the excess, cleaved fiber up and away from the ferrule.
4. Carefully dress the nub of the fiber with a piece of 12-micron alumina-oxide paper.
5. Do the final polishing

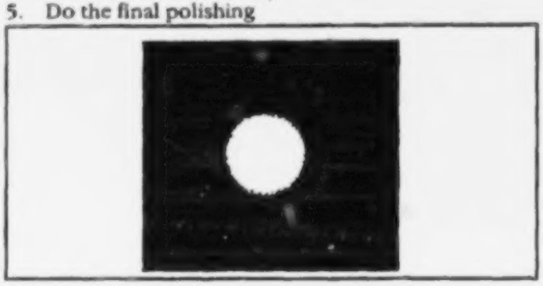

Figure 12 - A Well-Cleaved Multimode Fiber
(Courtesy of AMP, Incorporated.)

POLISHING

After a clean cleave has been achieved, the fiber end face is attached to a polishing brush, and the fiber is ground and polished. The proper finish is achieved by rubbing the connectorized fiber end against polishing paper in a figure-eight pattern approximately sixty times.

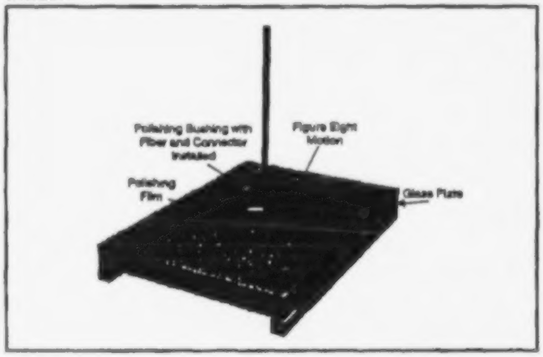

Figure 13 - Polishing Technique

To increase the ease and repeatability of connector installation, some companies offer connector kits. Some kits are specific to the type of connector to be installed while others supply the user with general tools and information for connecting different types of connectors. Some examples include Hewlett-Packard's Connector Assembly Tooling Kit, AMP, Incorporated's connector kits, or the line of field termination kits available from Fiber Instrument Sales.

Some connectors require the use of an alignment sleeve, also called an interconnection sleeve. This sleeve serves to increase repeatability from connection to connection. Figure 14 illustrates the use of an ST interconnection sleeve. When using SMA connectors, alignment sleeves, also known as half-sleeves or full-sleeves (depending on the length), are required to reduce insertion loss and improve performance. For more information on using SMA connectors and half-sleeves on Force links, see application note AN101.

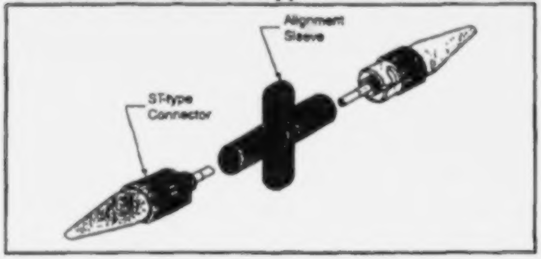

Figure 14 - ST Interconnection Sleeve

CARE AND HANDLING OF FIBER OPTIC CONNECTORS

The most important thing to remember in handling fiber optic connectors is that **the fiber end face and ferrule must be absolutely clean before it is inserted into a transmitter or receiver.** Dust, lint, oil (from touching the fiber end face), or other foreign particles obscure the end face, compromising the integrity of the optical signal being sent over the fiber. From the optical signal's point-of-view, dirty connections are like dirty windows. Less light gets through a dirty window than a clean one.

CLEANING

It is hard to conceive of the size of a fiber optic connector core Single-mode fibers have cores that are only 8-9 μm in diameter. As a point of reference, a typical human hair is 50-75 μm in diameter, approximately 6-9 times larger! Dust particles can be 20 μm or larger in diameter. Dust particles smaller than 1 μm can be suspended almost indefinitely in the air. A 1 μm dust particle landing on the core of a single-mode fiber can cause up to 1 dB of loss. Larger dust particles (9 μm or larger) can completely obscure the core of a single-mode fiber Fiber optic connectors need to be cleaned *every* time they are mated and unmated; it is essential that fiber optics users develop the necessary discipline to always clean the connectors before they are mated.

It is also important to cover a fiber optic connector when it is not in use. Unprotected connector ends are most often damaged by impact, such as hitting the floor. Most connector manufacturers provide some sort of protection boot. The best protectors cover the entire connector end, but they are generally simple closed-end plastic tubes that fit snugly over the ferrule only. These boots will protect the connector's polished ferrule end from impact damage that might crack or chip the polished surface. Many of the tight fitting plastic tubes contain jelly-like contamination (most likely mold release) that adheres to the sides of the ferrule. A blast of cleaning air or a quick dunk in alcohol will not remove this residue. This jelly-like residue can combine with common dirt to form a sticky mess that causes the connector ferrule to stick in the mating adapter. Often, the stuck ferrule will break off as one attempts to remove it. The moral of the story is always thoroughly clean the connector before mating, even if it was cleaned previously before the protection boot was installed.

CLEANING TECHNIQUE

Required Equipment:

- Kimwipes® or any lens-grade, lint-free tissue. The type sold for eyeglasses work quite well.
- Denatured Alcohol. Note: Use only industrial grade 99% pure isopropyl alcohol. Commercially available isopropyl alcohol is for medicinal use and is diluted with water and a light mineral oil. Industrial grade isopropyl alcohol should be used exclusively.
- 30X Microscope.
- Canned Dry Air.

1. Fold the tissue twice so it is four layers thick.
2. Saturate the tissue with alcohol.
3. First clean the sides of the connector ferrule. Place the connector ferrule in the tissue, and apply pressure to the sides of the ferrule. Rotate the ferrule several times to remove all contamination from the ferrule sides.
4. Now move to a clean part of the tissue. Be sure it is still saturated with alcohol and that it is still four layers thick. Put the tissue against the end of the connector ferrule. Put your fingernail against the tissue so that it is directly over the ferrule. Now scrape the end of the connector until it squeaks. It will sound like a crystal glass that has been rubbed

APPLICATION NOTE

AN 120

DECEMBER 1998

GENERAL FIBER OPTIC NETWORK DESIGN CRITERIA

INTRODUCTION

Increasingly networks are being converted from copper to optical fiber. As a result, network design procedures need to be adjusted to address the specific requirements of fiber optic cable as communications transport media.

This application note is written to provide **general** guidance and understanding of basic fiber considerations, while designing and specifying optical transmission equipment (OTP). In many cases, the equipment vendor will have to be contacted in order to fully understand the OTP parameters.

SAMPLE FIBER OPTIC DESIGN

Each span has a set of system design parameters and a set of transmission design calculations.

The following parameters (shown with its corresponding system element) must be considered:

Electronics	**Fiber Cable**	**System**
Tx Power	Attenuation	Optical Patch Panels
Rx Sensitivity	Dispersion	Future Upgrades
System Gain	Splice Loss	System Noise Penalties
	Splice Interval	-Bandwidth
	Repair Margins	-Modal Noise
		-Connector Reflection

As these parameters are addressed in a more detailed manner, the span transmission design requirements will be better understood.

KEY FIBER PARAMETERS

The two key parameters which affect the maximum possible repeater spacing and the maximum possible bit rate are attenuation (loss) and bandwidth (dispersion). Attenuation and bandwidth are independent parameters. Signal attenuation in fiber is expressed in dB/km. The dB (Decibel) is used for comparing two power levels and is defined as the ratio of the output power (P_O) to the input power (P_I): $dB = 10 \log (P_O/P_I)$. Because end-to-end fiber loss various linearly with length, the per unit performance is typically expressed as: $\alpha L = 10 \log(P_O/P_I)$ where α is the fiber loss per unit length in dB/km and L is the length in the same units, i.e., meter, kilometer, etc. In order to understand how critical each dB is to optical transmission, Table 1 breaks out the percentages of power losses for each dB

Force, Incorporated
Fiber Optics and Electronics

825 Park Street (PO Box 2045)
Christiansburg, VA 24073
(800) 732-5252 • (540) 382-0462
Fax: (540) 381-0392

E-Mail: force@forceinc.com
Web Page: www.forceinc.com

Table I - Power Loss Percentages

dB	Power out as a percentage of power in	Percentage of power lost	Remarks
1	78%	22%	
2	63%	37%	
3	50%	50%	1/2 the power
4	40%	60%	
5	31%	69%	
6	25%	75%	1/4 the power
7	20%	80%	
8	14%	86%	
9	12%	88%	
10	10%	90%	1/10 the power
20	1%	99%	1/100 the power
30	0.1%	99.9%	1/1,000 the power
40	0.01%	99.99%	1/10,000 the power
50	0.001%	99.999%	1/100,000 the power

Notice that with a 3 dB loss, there will be an equivalent 50% loss of optical signal. Because it is more economical and convenient to use lower power components, it is also more desirable to use low loss optical connectors and splicing techniques.

SYSTEM (NETWORK) REQUIREMENT:

Figure 1 illustrates the connection of optical transmission products (OTP) utilized for the transport of digital service between two remote locations. The procedure for specifying OTP requires some basic information. This information can be identified with the following formulas, based around three groups of information:

- Loss Budget Calculation
- Transmitter Optical Power Output
- Received Optical Power

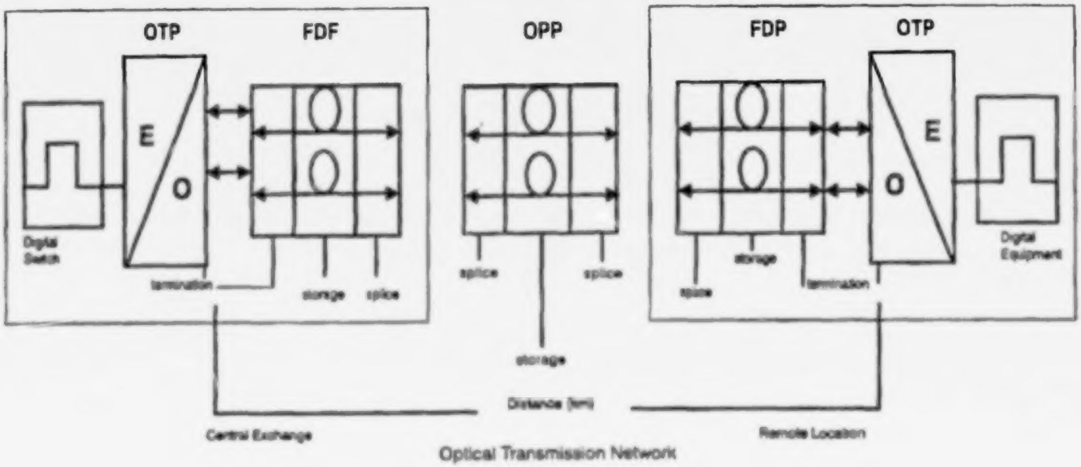
OTP
FDF
OPP
FDP
OTP
E
O
O
E
Digital Switch
termination
storage
splice
splice
splice
storage
storage
splice
termination
Digital Equipment
Distance (km)
Central Exchange
Remote Location
Optical Transmission Network

Figure 1 - Optical Transmission Network

Distance (km)	Total Installation Distance
E/O	Electrical to Optical Conversion
FDF	Fiber Distribution Frame
FDP	Fiber Distribution Panel
OSP	Outside Plant Pedestal
OTP	Optical Transmission Product
Splice	Network Optical Splice Location
Storage	Network Optical Storage Location
Termination	Network Optical Termination Location

SINGLE MODE LINK-LOSS WORKSHEET

Project		**Span**	
	Nominal: nm	Equipment	
Transmitter Wavelength	Minimum: nm	Manufacturer / Model	
	Maximum: nm	Maximum Receive Signal	dB
Bit Rate	Detector Type:	Receiver Sensitivity	dBm @ BER
A) Transmitter Output Power			dBm
B) Receiver Sensitivity			dBm
[redacted]			dB
D) Power Penalty Due to Dispersion (@ specified BER)			dB
E) Power Penalty Due to Other Miscellaneous Sources (connector reflections, modal noise, @ specified BER)			dB
F) Losses Due to Connectors (per manufacturer's specifications) (loss / connector =) x (number of connectors =)			dB
G) Losses Due to Installation Splice (loss / splice =) x (number of splices =)			dB
H) Margin for future Repair Splices			dB
I) Margin for future WDM Upgrade			dB
[redacted]			dB
K) Total Span Length			dB
[redacted]			dB/km
Determine Need for Optical Attenuator			
M) Likely Fiber Loss to be Delivered			dB/km
[redacted]			dBm
O) If (N) > Maximum Receive Signal, Optical Attenuator Required			Yes / No
NOTES:			

SINGLE MODE LINK-LOSS WORKSHEET

A) Transmitter Output Power

This information will be acquired from the optical product manufacturer.

B) Receiver Sensitivity

This information will be acquired from the optical transmission product manufacturer.

C) System Gain or Optical Budget

There will be two methods of identifying this figure. One method will be the result of subtracting the information in Section B from the information in Section A . The second will be to take the manufacture's specified optical budget figure if available. The optical budget will be the most accurate figure.

D) Power Penalty Due to Dispersion

This information will be related to the optical fiber utilized in the network (for general applications use 1.0 dB).

(Dispersion: A very short duration input pulse can be "stretched in time" or broadened as it propagates along the fiber core due to the dispersive effects of the fiber. The result is an output pulse which is wider in time than the input pulse. Broadening or stretching of the input signal introduces distortion which will cause bit errors.)

E) Power Penalty Due to Other Miscellaneous Sources

This is a concern at the higher bit rate systems (> 800 Mb/s). Transmission Engineers should approach the electronics vendor to get recommendations for the particular equipment, to determine the proper values (noise penalty in dB) for these power penalties.

F) Losses Due to Connectors

Take the manufacture's specified connector loss figure, multiply this figure by the total number of connectors in the network. There will be at least four (4) connectors in a system, one at the transmitter, one at the receiver, and one each at the transmit and receive optical patch panels.

G) Losses Due to Installation Splices

Take the loss per splice figure, and multiply that figure by the total number of splices.

The following formula can be used as an installation splice counting the procedure:

Number of splices = Number of Dig-Ups x 2

(Most companies are designing 2-3 dig-ups per span into their loss calculations.)

H) Margin for Future Repair Splices

For general calculations, with like fibers, a worst case figure would be 0.25 dB per splice.

Restoration (repair) splices represent the margin for future cable resulting from dig-ups. Typically two or three dig-ups per span are engineered into the loss calculations. Most dig-ups require the insertion of a short piece (two splices) of fiber-optic cable to replace the damaged section. This piece is usually several meters long. This is why "identical" fibers as written in section G, are typically never spliced together under field conditions.

I) Margin for Future WDM Upgrade

Wavelength-division Multiplexing (WDM) can be implemented by transmitting and receiving on the same fiber (bidirectional) or by transmitting multiple wavelengths (unidirectional) in one direction along the fiber.

J) Maximum Allowable Cable Loss

In order to identify the total loss of the span, take the number from the Section C (system gain) and subtract this number with the numbers identified in Sections D,E,F,G,H and I (C-D-E-F-G-H-I).

K) Total Span Length

This number will identify the total length of the span being designed.

L) Maximum Allowable Fiber Loss

This figure will be the result of the figure in Section K divided by the figure in Section J (J/K).

M) Likely Fiber Loss to be Delivered

This will be the figure given in Section L.

N) Likely Maximum Receive Signal Level

To determine the maximum signal level, assume

Cable Loss = 0.4dB x "Total Span Length"

Connector Losses = 0.5 dB Each

Splice Losses = 0.15 dB Mean

O) Optical Attenuator

Compare the figure identified in Section N with the manufacture's specified "Maximum Receive Signal" or "Receiver Dynamic Range." If the figure indicated in Section N is greater than the manufacture's figure, attenuation will be required.

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Technical Note
November 1995

AT&T
Microelectronics

Power Margin Analysis

Introduction

The design of an efficient fiber-optic communication system includes the evaluation of the power margin. Proper operation of an optical system depends on modulated light reaching the receiver with enough power to be accurately demodulated.

There are several variables that affect the power of the light transmitted to the receiver. The passive media components (cabling, splicing, and connectors) add various amounts of attenuation to the signal.

As the light travels through the fiber, it is also affected by chromatic dispersion (spreading of the signal pulse because of the different wavelength speeds) and modal dispersion (spreading of the signal pulse because of the different propagation modes in the fiber). Chromatic and modal dispersion are combined into a dispersion penalty (dB) that reduces the power margin of the system (see Dispersion Penalty section).

The power margin is a measure of power reaching the receiver in excess of the minimum power required for the receiver to operate properly. An excessive power margin can be used to extend the system length or to build in flexibility for rearrangement by adding splices and connectors.

An insufficient power margin indicates poor system design practices and can contribute to a high error rate. A linear, worst-case analysis has been the most popular method in determining the power margin of a link. However, statistical methods can provide a more accurate power margin analysis.

Linear Worst-Case Method

In the first-order approximation of the worst-case power margin, minimum transmitter power, maximum link loss, and minimum receiver sensitivity are assumed. The following simple equation is used to estimate the power margin.

$P_M = P_T - P_R - LL$ (dB)

where P_M = power margin (min)
P_T = power out of the transmitter (min)
P_R = power sensitivity of receiver (min)
LL = estimated link loss (max)

The link loss variable (LL) includes 0.5 dB for higher-order losses in multimode fiber, 1 dB for a clock recovery module, and a value for modal and chromatic dispersion (depending on the fiber and wavelength used). Known values for connector loss, splice loss, and fiber attenuation should also be included in the calculation.

The worst-case analysis method provides a conservative estimate. Not all of the components in an actual system will be performing at their worst-case values. Instead, the performance of the components will be statistically grouped around the individual mean values. Sophisticated statistical models and analysis techniques permit system designers to customize lightwave systems for greater efficiency and lowest system cost for a particular application.

Statistical Power Margin Method

Basic Model

A statistical model evaluates the link loss as the mean plus two times the square root of the sum of the sigmas (σ) of the loss components squared. The model includes terms to account for dispersion and higher-order mode loss. The total link loss is then compared to the mean transmitter power, minus the mean receiver sensitivity, to determine the mean system power margin. Since each of the power quantities is essentially a normally distributed random variable, the power margin is characterized by the following:

Equation 1

$$\mu_M = \mu_t - \mu_r - [\mu_c L + \mu_{co} N_{co} + \mu_s N_s + \mu_D + \mu_H + \mu_{CR}]$$

Statistical Power Margin Method

(continued)

Basic Model (continued)

Equation 2

$$\sigma M = [\sigma t^2 + \sigma r^2 + \sigma c^2\, LLs + \sigma co^2\, Nco + \sigma s^2\, Ns + \sigma D^2 + \sigma H^2 + \sigma CR^2]^{1/2}$$

While these equations are applicable for both multimode and single-mode digital systems, this document emphasizes single-mode systems with laser sources; multimode data is included for completeness only.

Table 1 defines terms, units, and term values of the equations. AT&T building and plant cable are specified at a maximum loss, which is handled in the statistical model by setting μc equal to the maximum building cable loss and the σc equal to zero. This specification methodology is the same for AT&T single-mode fibers.

The fiber cable parameters are given in Table 2. The mean (μH) and sigma (σH) for the LED-generated higher-order mode loss are assumed to be 0.5 dB and 0.0 dB, respectively, but both are set to zero for single-mode fibers.

Higher-order mode loss accounts for the difference between factory cable measurements of steady-state loss and the field values for a short system. Higher-order mode loss results from small fraction of light from an LED optical source being launched into a fiber in radiative modes. The light in these modes radiates into the fiber cladding after a short distance. The link loss is defined as the sum of component, dispersion, and modal losses.

Other terms in Table 1 are evaluated from equations or other tables as indicated, or defined as input for the specific application.

Table 2 details cable parameters for outside plant and building cables at both short (850 nm) and long (1300 nm and 1500 nm) wavelengths. The mean and standard deviations given in Table 3 characterize typical AT&T optical devices at various wavelengths and data rates.

Table 4 shows the parameters for several popular connectors and splicing methods. For links involving more than one type of connector or splice, a separate term is included in both equations 1 and 2 for each type. Different cable types will also require separate terms.

Table 1. Statistical Model Terms

Symbol	Term	Value	Unit
μt	Mean transmitter power	Table 3	dBm
σt	Sigma transmitter power	Table 3	dB
μr	Mean receiver sensitivity	Table 3	dBm
σr	Sigma receiver sensitivity	Table 3	dB
μc	Mean cable loss	Table 2	dB/km
σc	Sigma cable loss	Table 2	dB/km
μco	Mean connector loss	Table 4	dB/connect
σco	Sigma connector loss	Table 4	dB/connect
Nco	Number connectors	Input	—
μs	Mean splice loss	Table 4	dB/splice
σs	Sigma splice loss	Table 4	dB/splice
Ns	Number splices	Input	—
L	System length	Input	km
Ls	Average section length	Input	km
μD	Mean dispersion penalty	Calculation	dB
σD	Sigma dispersion penalty	0.3*	dB

* Considered 0.0 dB for single-mode fiber applications.

Statistical Power Margin Method (continued)

Basic Model (continued)

Table 1. Statistical Model Terms (continued)

Symbol	Term	Value	Unit
μH	Mean higher-order mode loss	0.5*	dB
σH	Sigma higher-order mode loss	0.0*	dB
μM	Mean link margin	Output	dB
σM	Sigma link margin	Output	dB
μCR	Mean clock recovery module loss for T7032 (50 Mbits/s), T7035 (50 Mbits/s—250 Mbits/s)	 1.5 0.5	 dB dB
σCR	Sigma clock recovery module loss for T7032 (50 Mbits/s), T7035 (50 Mbits/s—250 Mbits/s)	 0.25 0.25	 dB dB

* Considered 0.0 dB for single-mode fiber applications

Table 2. Standard AT&T Fiber Parameters for Outside Plant Cable and Building Cable

Cable Type	**8/125 μm, Single-Mode Fiber**					
	1300 nm			**1500 nm**		
	Loss (dB/km)		**Dispersion (ps/nm-km)**	**Loss (dB/km)**		**Dispersion (ps/nm-km)**
	Max	**Sigma**		**Max**	**Sigma**	
Outside Plant	0.35/0.4	0	2.8 (max)	0.23/0.3	0	18 (max)
Building	0.4	0	2.8 (max)	0.3	0	18 (max)
Cable Type	**62.5/125 μm; NA 0.275**					
	850 nm*			**1300 nm**		
	Loss (dB/km)		**Bandwidth MHz-km**	**Loss (dB/km)**		**Bandwidth MHz-km**
	Mean	**Sigma**		**Mean**	**Sigma**	
Outside Plant	3.4	0	200 (min)	1	0	500 (min)
Building	3.4	0.0	200 (min)	1	0	500 (min)

* Loss at 870 nm is approximately 0.32 dB/km less than at 850 nm. Loss at 825 nm is approximately 0.38 dB/km more than at 850 nm.

Note: These parameters are for AT&T fiber only and are subject to change without notice.

Statistical Power Margin Method (continued)

Basic Model (continued)

Table 3. Optical Device Parameters

Device	Part	Description	Power Output*		Receiver Sensitivity (BER = 10^{-9})†	
			Mean (dBm)	Sigma (dB)	Mean Avg. Power (dBm)	Sigma (dB)
Laser Transmitter	1227P	OC-3 TX, 1300 nm	–11	0.15	—	—
Laser Transmitter	1237J	Receptacled, OC-3 TX, 1300 nm	–4.9	0.5	—	—
Laser Transmitter	1227AF	OC-12 TX, 1300 nm	0.1	0.15	—	—
SONET Receiver	1310C	OC-3 RX	—	—	–38.1	0.48
SONET Receiver	1310MC	OC-12 RX	—	—	–32.0	0.28
SONET Receiver	1310PC	OC-12 RX	—	—	–32.1	0.98
Fibre Channel Receiver	1318A	1.5 Gbits/s RX	—	—	–27.4 (1.5 Gbits/s) –28.7 (1.062 Gbits/s)	0.58 (1.5 Gbits/s) 0.74 (1.062 Gbits/s)
SONET Receiver	1320C	OC-12 RX with Clock Recovery	—	—	–31.5	0.3

* Average power coupled into 8 µm pigtailed fiber at room temperature and beginning of life.

† Receiver sensitivity varies with bit-error-rate (BER) requirements. A change of three orders of magnitude in the BER requires a 1 dB change in optical power.

Note: These parameters may change without notice as the database for each part is increased and they should not be considered a specification of the device

Table 4. Connector and Splicing Component Loss

Connectors	50/125 µm		62.5/125 µm		8/125 µm	
	Mean (dB)	Sigma (dB)	Mean (dB)	Sigma (dB)	Mean (dB)	Sigma (dB)
ST® II	0.5	0.2	0.40	0.20	0.35	0.20
SC	0.3	0.2	0.25	0.15	0.12*	0.08
FDDI-MIC	—	—	0.50	0.25	—	—
ESCON	—	—	0.30	0.20	0.40	0.30
FC-APC (non-AT&T)	—	—	—	—	0.09	0.05
Splices						
Rotary Splice	0.25	0.10	0.25	0.10	0.20	0.10
CSL	0.15	0.10	0.15	0.10	0.15	0.10

Tuned

Dispersion Penalty

Quite often, the factor that limits the distance in a fiber-optic system is the dispersion in the optical cable. Dispersive effects in the fiber fall into one of two categories: modal or chromatic. Depending on the source used and the fiber type, the dispersion may be dominated by one of these types or a combination of both. Table 5 shows the relationship of modal dispersion and chromatic dispersion for these options.

Intuitively, one can see that modal dispersion is only a factor in multimode fibers. In these fibers, there might be hundreds of modes propagating in the fiber core. Since each mode takes a slightly different path, they will arrive at the end of the fiber at different times. The result is a broadening of the optical pulse signal. This effect is reduced substantially by using graded-index fiber. Although this tends to make the arrival times almost the same, there still will be some modal dispersion. If the pulses become too broad, leading and trailing pulse edges can overlap causing intersymbol interference and an increase in the bit-error rate (BER) of the system.

Similarly, chromatic dispersion also broadens the pulses and causes intersymbol interference. In this case, the problem lies in the range of wavelengths emitted by the source. The fiber's index of refraction is slightly dependent on the wavelength. Therefore, different wavelengths will propagate with different speeds in the fiber. Because LED sources emit over a broad range of wavelengths, chromatic dispersion is critical. Lasers emit over a much narrower spectral width, and in multimode fiber, the dominating effect is modal dispersion.

In single-mode fiber, which by definition cannot have modal dispersion, chromatic dispersion will dominate.

The degrading effects of dispersion can be compensated in system design by increasing the optical power into the receiver, which increases the signal-to-noise ratio (SNR). The key is to determine exactly how much power is required to compensate a particular system. The amount of increased power needed is referred to as the dispersion penalty because this power directly reduces the amount of power in the system link budget. If a statistically random method is used, the mean dispersion penalty is calculated and then the standard deviation for loss budget calculations is used. For the case of single-mode fibers, the general method has been to consider worst-case dispersion values.

Based on Table 5, there are four combinations of sources and fibers that could be possible. However, one combination is not likely to occur. This case is using an LED source with a single-mode fiber. Surface-emitting LEDs do not have enough power to couple appreciative amounts into the small core of a single-mode fiber. (Edge-emitting LEDs can couple useful amounts of light into a single-mode fiber.) Because of this, LEDs are simply not used in single-mode applications, or only in cases where the link distance is very short. That leaves three possibilities to be examined: laser sources into single-mode fiber, LED sources into multimode fiber, and laser sources into multimode fiber. Although not directly applicable to AT&T's current laser offerings, the case of LED sources into multimode fiber is included in an effort to show the derivation of the dispersion penalty, μD.

Table 5. Mechanisms Limiting Fiber Bandwidth

Source	**Fiber Type**	
	Multimode	**Single Mode**
Laser	Modal	Chromatic
LED	Modal and Chromatic	Chromatic

Dispersion Penalty (continued)

Laser Sources into Single-Mode Fiber

By definition, the dispersive effect in single-mode fibers is dominated by chromatic dispersion. (There are actually two polarization modes traveling down the fiber, which can give rise to polarization-mode dispersion (PMD). However, PMD tends to be of importance for analog systems and very high bit-rate, long-distance digital systems, but does not play a large role in the digital systems discussed in this application note.) For conventional transmission systems, there are two optimal wavelength windows centered around 1310 nm and 1550 nm. Standard single-mode fiber has a zero-dispersion wavelength, λo, around 1310 nm.

Dispersion-shifted fiber places λo around 1550 nm. If a laser source were ideal, with no line width, and if it were at the right wavelength, there would be no chromatic dispersion in the system. Real-world line widths and fibers, though, dictate that there will be chromatic dispersion.

Long-distance applications using lasers as the sources and single-mode fibers as the transmission medium ave taken a worst-case approach to the dispersion enalty.

A system is allowed to have a dispersion penalty of 1 dB—2 dB, and using these figures, allowances can be made for the dispersion in the fiber and for the spectral width of the source. This approach is used by SONET and Bellcore to handle the short-, medium-, and long-reach applications.

Dispersion specifications are derived through consideration of the allowable pulse broadening as a fraction of the time-slot width, ε.

Equation 3

$$\varepsilon = 10^{-6} (BR) (D_{MAX}) (\delta\lambda)$$

where the BR is in Mbits/s, D_{MAX} is the maximum dispersion (ps/nm) for the system distance, and $\delta\lambda$ is the spectral width (nm).

For multilongitudinal-mode (MLM) lasers, $\delta\lambda$ is the root-mean-square spectral width, and for single longitudinal-mode (SLM) lasers, $\delta\lambda = \Delta\lambda 20/6.07$ This is the Gaussian spectral width at the 20 dB down point.

Empirical and analytical modeling as referenced in the Bellcore document TR-NWT-000253 (Issue 2, 1991), provides the relationship between ε and dispersion penalty for various laser types, as shown in Table 6. Most SONET systems allow for a 1 dB or 2 dB intersymbol/interference dispersion penalty. MLM lasers, for example, have $\varepsilon = 0.115$ for a 1 dB penalty. That is, the pulses may broaden by up to 11.5%, to keep the dispersion penalty down to 1 dB or less. The MLM case is more strict because there is mode-partition noise in the laser, which also contributes to intersymbol interference. For long-haul SONET applications at the OC-18, OC-24, and OC-48 rates, where a 1550 nm source is used in dispersion-shifted fiber, a 2 dB dispersion penalty is usually allowed. For OC-48 systems, this model might not accurately account for the dispersive effects of laser chirp.

With ε known and using a source with a known spectral width, the quality of the fiber or the distance can be chosen to satisfy the dispersion penalty. For example, AT&T 8.3 µm single-mode fiber has a maximum dispersion of 3.2 ps/nm-km in the 1310 nm window. Using an MLM laser with $\delta\lambda = 4$ nm at 622 Mbits/s, the maximum dispersion for a 1 dB penalty would be $D_{MAX} =$ 46.2 ps/nm. Thus, the allowed distance would be 14.4 km. It is important to note that this distance is simply the dispersion-limited distance for a 1 dB penalty. A typical system would span a much greater distance before it becomes attenuation limited. With a lot of extra optical power available, a system can tolerate a larger dispersion penalty and can thus go longer distances. This practice, however, cannot be extended indefinitely; it is recommended not to exceed a 2 dB dispersion penalty. (See system example.)

Table 6. Pulse Broadening vs. Dispersion Penalty for Various Laser Types

Laser Type	Dispersion Penalty	ε
Multilongitudinal Mode	1 dB 2 dB	0.115 0.182
Single-longitudinal Mode	1 dB 2 dB	0.306 0.491

Dispersion Penalty (continued)

LED Sources into Multimode Fiber

For systems using surface-emitting LEDs, the dispersion penalty in dB is related to the square of the data rate and the square of the total exit LED bandwidth of the fiber as follows:

Equation 4

$$\mu D = 0.88\left[\frac{BR}{BW_{TOTAL}}\right]^2$$

for short wavelength (850 nm) and

Equation 5

$$\mu D = 1.2\left[\frac{BR}{BW_{TOTAL}}\right]^2$$

for long wavelength (1300 nm), where BR is the bit rate (Mbits/s) and BW_{TOTAL} is the total exit LED bandwidth of the system (MHz).

From Table 5, it is apparent that this BW_{TOTAL} must take into account the effects of both modal and chromatic dispersion. These two effects are combined statistically as follows:

Equation 6

$$BW_{TOTAL} = \frac{(BW_{CHROM})(BW_{LASER})}{[(BW_{CHROM})^2 + (BW_{LASER})^2]^{0.5}}$$

The bandwidth due to modal dispersion is equivalent to the laser bandwidth (BWLASER) because, in general, a laser source only suffers modal dispersion when launched into multimode fiber. When specifying multimode fiber, the spooled fiber bandwidth (BWF) is measured with a laser source. The laser bandwidth is related to the measured BWF, but it has to take into account the following effects:

- Changes in fiber bandwidth when the fiber is unwound from spools of various diameters and packaged into a cable (cut-back length scaling and packaging effects)
- Changes in bandwidth when the cables are unwound from their reels and installed (installation effects)
- How the bandwidth of the fibers in the individual cables combine when fibers in adjacent cables are spliced together
- The total system length (L) and the average section length (LS), which is the total length divided by the number of splices in the fiber plus one.

The result is that the BW_{LASER} is proportional to the BWF and related to total system length and average section length by

Equation 7

$$BW_{LASER} \propto k(BW_F)\, L^{-\gamma}\, L_S^{-\beta}$$

where k, γ, and β are all <1. The reduction factor, k, accounts for a lower bandwidth when cables are unreeled and installed. The terms γ and β are the concatenation scaling factors for the total length and average fiber length, respectively. The term reflects the adage, "The sum is greater than the whole." Due to modal mixing at splice points, the bandwidth of many short pieces of cable actually scales more favorably than the bandwidth of a few long pieces.

The second dispersive effect, chromatic dispersion, is accounted for in the chromatic bandwidth of the fiber, BW_{CHROM}. This is where the center wavelength and spectral width of the LED source plays a role. Roughly, the chromatic bandwidth is related to the system length, spectral width, center wavelength, and minimum dispersion wavelength of the fiber, λ_{MIN} as follows:

Equation 8

$$BW_{CHROM} \propto \frac{L^{-0.7}}{(FWHM)^{0.5}|\lambda_C - \lambda_{MIN}|}$$

As expected, one would want as narrow a line source as possible, centered as close as possible to the minimum dispersion wavelength (usually about 1310 nm).

These two dispersion bandwidths can be combined into the total exit LED bandwidth, and the following equations are based on AT&T fibers and typical spectral profiles of LEDs.

There are four cases to consider:

Equation 9

Short wavelength (850 nm—870 nm), 50/125 μm, 0.23 NA fiber:

$$\frac{1}{(BW_{TOTAL})^2} = \frac{L^{1.96}}{(92.9)^2} + \frac{L^{1.8}}{(0.77\ BWF)^2}$$

Equation 10

Short-wavelength (850 nm—870 nm), 62.5/125 μm, 0.275 NA fiber:

$$\frac{1}{(BW_{TOTAL})^2} = \frac{L^{1.8}}{(65.3)^2}$$

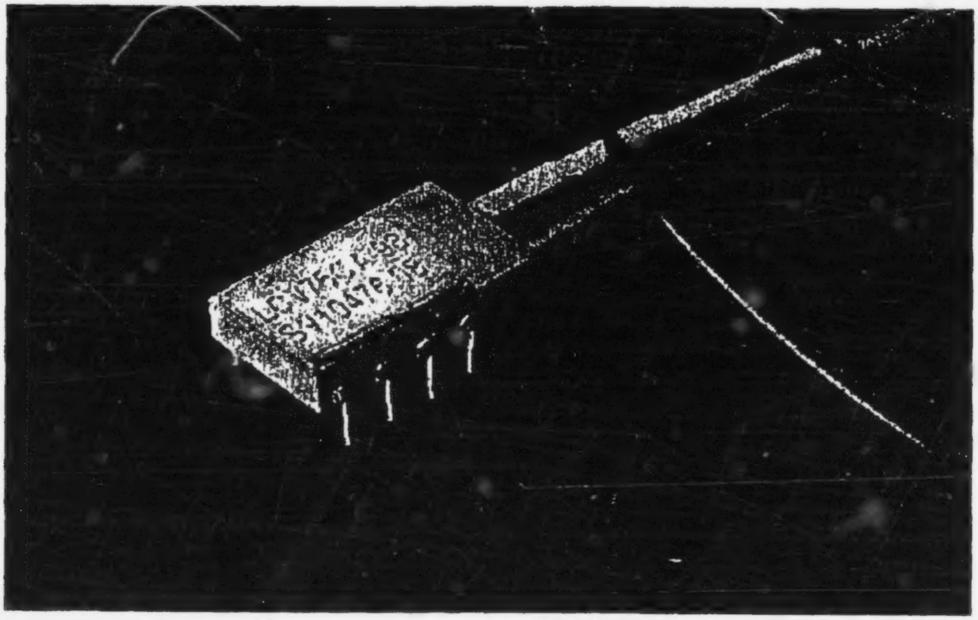
List of Abbreviations

β	Concatenation factor for average system length
BER	Bit-error rate
BR	Bit rate
BW_{CHROM}	Chromatic bandwidth of the fiber
BWF bandwidth	Fiber manufacturer's measured laser
BW_{LASER}	Modal bandwidth of the fiber
BW_{TOTAL}	Total exit LED bandwidth of a fiber
dB	Decibel
DSF	Dispersion-shifted fiber
D_{MAX}	Maximum dispersion in a system
ε	Allowable pulse broadening in a system
FWHM	LED source 3 dB spectral width
k	Reduction factor for cable unreeling and installation
ED	Light-emitting diode
Mbits/s	Megabits per second
MLM	Multilongitudinal mode
MM	Multimode
OC	Optical carrier
PMD	Polarization-mode dispersion
RMS	Root mean square
SLM	Single-longitudinal mode
SNR	Signal-to-noise ratio
SONET	Synchronous Optical Network
δλ	Spectral width of laser source
XCVR	Transceiver
γ	Concatenation factor for total system length
λ_c	Center wavelength of the source
λ_{MIN}	Wavelength for minimum fiber dispersion
λ_o	Zero-dispersion wavelength of single-mode fiber

APPLICATIONS NOTE

NORTEL
NORTHERN TELECOM

LCV75 Series 1300nm Mini-DIL Transmitters



Nortel plc
Optoelectronics
Paignton
Devon
ENGLAND

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Contents (Continued)

FEATURES

- Wavelength 1310nm.
- Silicon-V-groove fibre alignment technology.
- Nortel's GaInAsP VHT RWG laser chip designed for extended temperature operation.
- Isolated internal fast InGaAs monitor photodiode.
- Proven reliability and Bellcore TA-NWT-000983 capability.
- Hermetically sealed package.
- 8/125μm cladding mode stripped fibre pigtail.
- Maximum data rate in excess of 622Mbit/s.
- Footprint compatible with 14 pin DIL series.

APPLICATIONS

- Telecommunications - 155/622Mbit/s Long and intermediate reach
  - SDH/SONET/ATM
  - L.1.1/L4.1

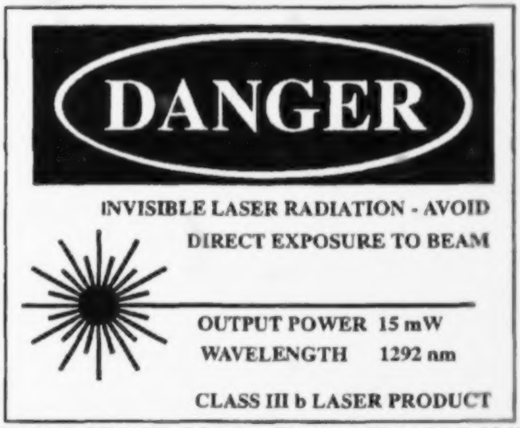
DESCRIPTION

The LCV series are state-of-the-art optical transmitters. They use Nortel's patented Silicon-V-groove fibre alignment technology and provide industry leading stability and exceptional reliability performance. Nortel's unsurpassed reputation for innovation and quality is embedded in a rugged, hermetically sealed fibre-tailed ceramic package capable of satisfying the requirements of the Bellcore quality specification TA-NWT-000983.

The Ridge Waveguide laser chip has been specifically developed for operation over an extended temperature range. The rear facet monitor diode is optimised to provide a fast response enabling either conventional mean power control or individual bit monitoring at speeds in excess of 622Mbit/s.

The LCV series is compatible with Nortel's PTAV family of Mini-DIL receivers.

SAFETY AND HANDLING PRECAUTIONS



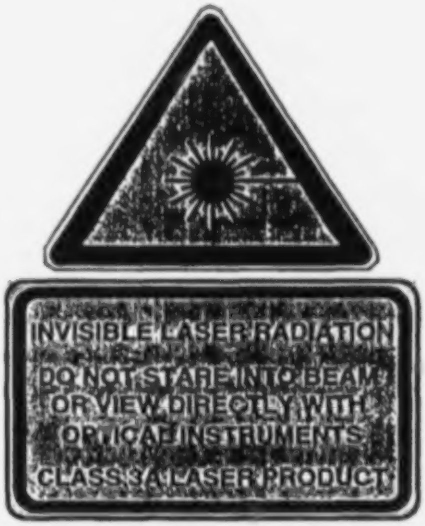
DANGER

INVISIBLE LASER RADIATION - AVOID DIRECT EXPOSURE TO BEAM

OUTPUT POWER 15 mW
WAVELENGTH 1292 nm

CLASS III b LASER PRODUCT

THIS PRODUCT COMPLIES WITH 21CFR 1040.10



INVISIBLE LASER RADIATION
DO NOT STARE INTO BEAM
OR VIEW DIRECTLY WITH
OPTICAL INSTRUMENTS
CLASS 3A LASER PRODUCT

REFERENCE IEC 825-1:1993

Optical

The LCV Mini-DIL range has been assessed against international optical safety standards and are classified IIIb in accordance with 21C FR1040.10 and 3a in accordance with IEC 825-1:1993.

1310nm radiation is invisible to the human eye but under certain circumstances exposure may be harmful. Always avoid direct exposure of eyes to laser radiation emitted either directly from laser diodes, or from the exposed end of the fibre optic cables.

Prior to commencing using semiconductor lasers we advise you to review the relevant national and international standards and to take the associated safety precautions. Workers directly concerned with devices should be educated in their safe usage and made aware of potential hazards.

Test fixtures and jigs are normally designed with fail-safe interlocks to prevent inadvertent exposure to radiation.

Flammability

The external materials are a ceramic and metal package, secondary coated fibre and silicon free protective boot. These do not constitute a hazard under normal operation. However, burning of these may result in toxic gas formation.

Handling Precautions

Like most active semiconductor components, optoelectronic devices are susceptible to damage from electrostatic discharge and surge currents. To reduce this risk to the device, suitable precautions must be taken during system circuit design and during device test and measurement.

Surge and Electro-Static-Discharge

Electrostatic discharge and transient high energy current pulses may damage semiconductor diodes. High levels of static charge may be generated and carried by the human body or on non-conductive non-dissipative materials. Nortel recommend that as a minimum the following precautions should be taken when handling devices:

- Reduce body charge by connecting operators to ground via a non metallic carbon wrist strap.(Resistance of 500 Ohms to 1 MOhm).
- Commonly ground the measuring and inspecting equipment and the work stations.
- All assembly and test operations should be conducted in shielded rooms with static dissipative flooring.
- Assemble and test devices while performing ion blowing or in a weak minus ion atmosphere.
- Open shipment cartons only at point of use.
- Control temperature and humidity. Humidity should be 50% ±10%.

Power Supplies

Ripple eliminating noise filters should be fitted to all mains power supplies serving measuring and testing equipment.

In addition all test jigs should be fitted with Germanium Schottky protection diodes - in parallel with laser. These should be sufficiently fast (<5ns), and have low forward voltage (<500mV).

Always stop work following power supply interruptions. Remove and disconnect optoelectronics devices before resetting equipment and recommencing test.

Soldering

Always keep lead soldering times and temperatures to a minimum.

Only use temperature controlled 'earthed tip' or battery operated soldering irons.

Nortel recommends a maximum temperature of 260 °C, and a maximum duration of 10 secs with the iron tip no closer than 2mm from a laser body.

Storage

Where possible, store optoelectronic devices at a temperature between 10°C and 30°C with a relative humidity of below 40%.

Avoid sudden sharp drops in temperature.

Always keep devices in primary packaging, ideally in an ESD free area.

Fibre Handling Precautions

Fibre tail is single mode 9/125um with a 0.9mm Hytrel secondary coat. Please note this is not a ruggedised fibre, (maximum tensile fibre pull 10N). Strain relief is provided at the device end of the fibre in the form of a rubber boot. Appropriate precautions should be taken when handling the fibre tail avoid kinking, twisting or pulling the fibre excessively, and to observe the minimum bend radius of 35mm.

THE ABSOLUTE MAXIMUM RATINGS

The following listing of absolute ratings are designed for guidance only.

Exceeding these conditions may result in damage to the component.

Under default operation the device will withstand any one of these conditions for a short duration without an adverse affect upon the long term reliability.

Absolute Maximum Ratings:-

Parameter	**Symbol**	**Min**	**Max**	**Unit**
Operating case temperature	T_{op}	-40	+85	°C
Storage temperature	T_{sg}	-40	+85	°C
Forward current (-40°C)	I_f		Ith+60	mA
Forward current (+85°C)	I_f		Ith+100	mA
Reverse voltage (25°C)	V_R		1.0	V
Monitor bias voltage (25°C)	V_{PDR}		-20	V
Fibre bend radius		35		mm

Circuit for Driving LCV** Mini-DIL Lasers

The present trend is to operate Laser devices or modules from a single 5V rail. In order to operate the laser at high speed and draw a constant mean current, the laser is placed in one arm of a long tail pair as shown in a simplified schematic Fig 1. Transistor T3 controls the amount of modulation current through the laser and differential signal applied to the bases of T1 and T2 via Data+ and Data- switches the current through either R1 or the laser.

The resistor R1 is included to balance the longtail pair by providing equivalent series resistance. It should be in the order of 5Ω.

In order to switch the laser at high speeds and to prevent excessive optical overshoot, the laser needs to be biased slightly above threshold so that it is lasing. In order to do this a constant DC current is sunk through the laser via an inductor and transistor T4. The modulation current Imod is thus added to the bias current Ibias to provide a modulated optical output as shown in Fig 2.

The laser can be driven in an open or closed loop configuration. In open loop the modulation and bias current is set up at start of life at a particular temperature. The threshold of the laser will rise over temperature and life and consequently optical power will not remain constant. To compensate for any changes, the laser can be driven in a closed loop configuration. Light from the back facet of the laser falls onto the Back Facet Monitor which provides a DC output when a suitable capacitor is connected in parallel with it. This is used in a negative feedback loop to maintain a constant optical power by controlling the amount of bias current and is shown in Fig 1.

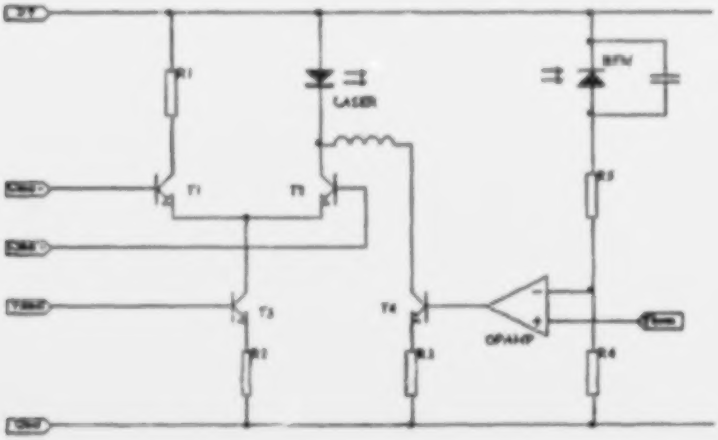


Figure 1 : Laser Drive Circuit

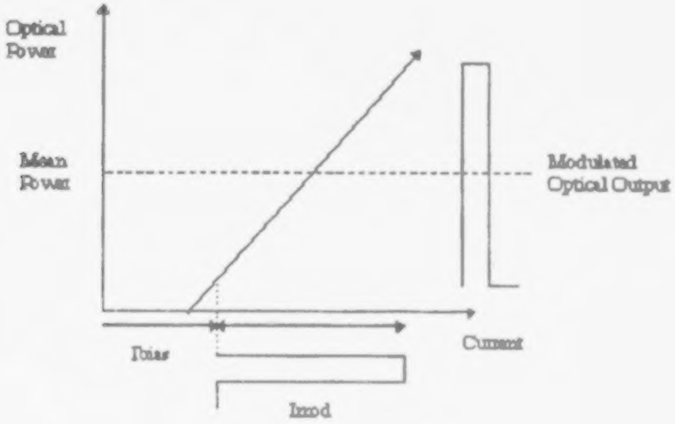


Figure 2 : Laser Modulation

Nortel's A0685475 Laser Diode driver IC's offer a low cost solution to driving lasers and provide a simple way of implementing the circuit above with a minimum of external components. The circuit is shown in Fig 3 and can be used for data rates of up to 622 Mbits^{-1}.

C4	2.2uF	Tantalum power supply filter capacitor
R10	4k7	Laser disable pulldown resistor. This enables the laser driver with no input to the disable pin.
R12		Equivalent laser and series resistance
R4	100R	Two 50Ω terminating resistors
C1	220nF	Power supply decoupling
C2	220nF	Back Facet Monitor capacitor
L1	Ferrite	Bias inductance
U2	Laser	
U1	Laser Driver IC	
R1	Lim Set	Sets the maximum bias current to the laser
R2	Mod Set	Sets the modulation current
R13	Power Set	Sets the optical power output
R3		Additional laser series resistance
C3		Snubber capacitor
R9		Snubber resistor
T2	Thermistor	Slope efficiency compensation thermistor

This circuit has additional components to the circuit shown above which can be added if required. A snubber network is incorporated across the laser to modify the rising edge speed. Selection of appropriate components can optimise the eye shape to ensure that it will pass a mask test when the laser is used in SDH/Bellcore applications.

It can be seen from Fig 2 that if the slope efficiency of the laser degrades over temperature and life the ratio of "1"s and "0"s to the dark level will change. A negative coefficient thermistor across the modulation set resistor can be used to increase the modulation current as the slope efficiency decreases with temperature. Slope efficiency ageing needs to be compensated for by setting the laser extinction ratio with adequate margin for degradations over life.

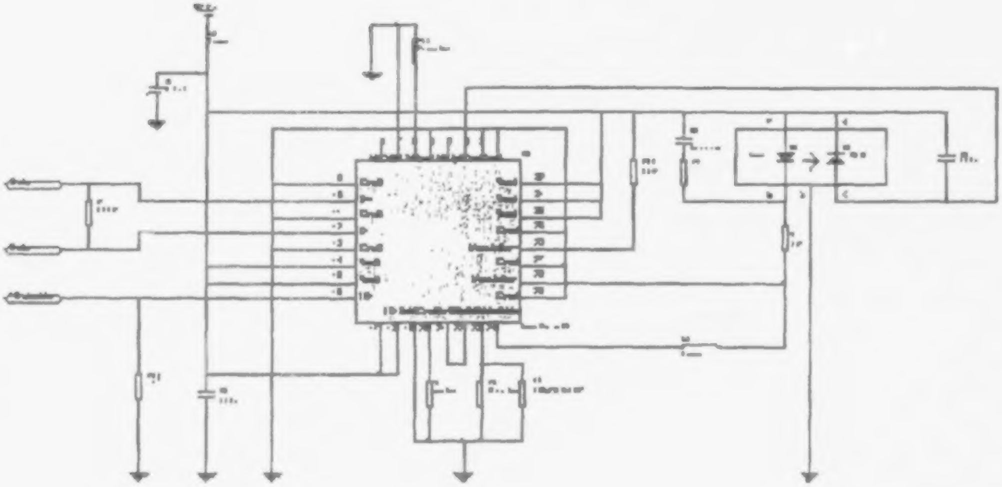


Figure 3 : Laser Drive Circuit Incorporating Nortel Driver IC

Mini-DIL and Coaxial Board Layouts:-

Fig 4 illustrates a suggested PCB configuration that allows coaxial, 14 pin DIL and 8 pin Mini-DIL options.

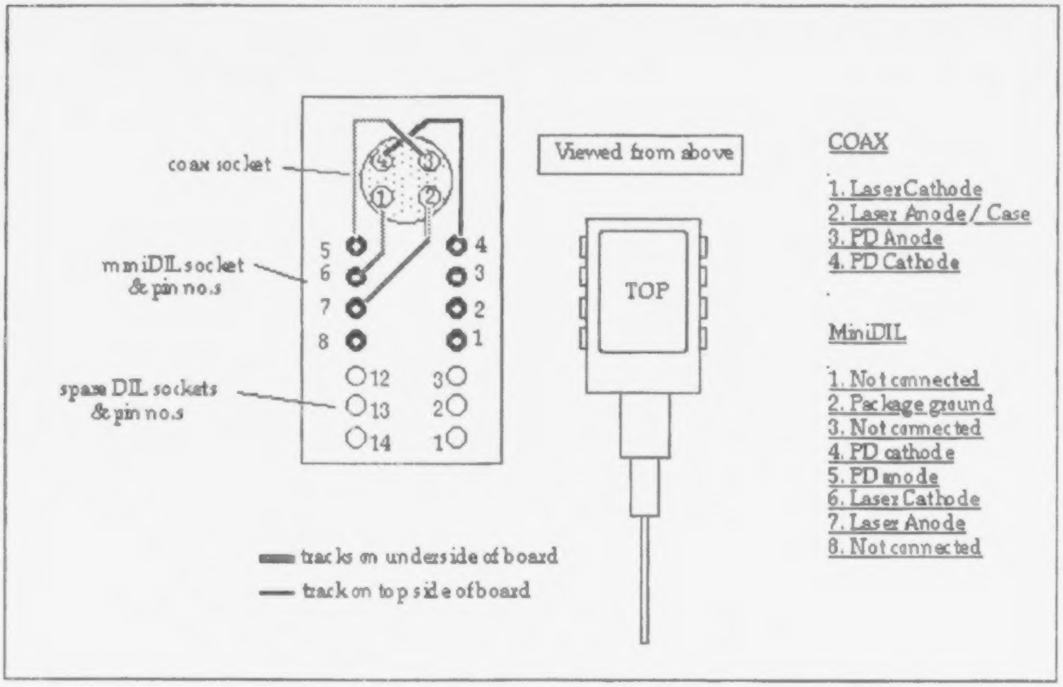

coax socket
mini DIL socket & pin no.s
spare DIL sockets & pin no.s
① ② ③ ④
5 6 7 8
4 3 2 1
12 13 14
3 2 1
Viewed from above
TOP
tracks on underside of board
track on top side of board
COAX
1. Laser Cathode
2. Laser Anode / Case
3. PD Anode
4. PD Cathode
MiniDIL
1. Not connected
2. Package ground
3. Not connected
4. PD cathode
5. PD anode
6. Laser Cathode
7. Laser Anode
8. Not connected

Figure 4 : Suggested PCB Track Configuration

The Mini-DIL has been designed as a drop in replacement for the 14-pin DIL devices and can be placed directly in the 14-pin socket. Mini-DIL pins 1-8 need to occupy DIL sockets 4-11 respectively.

Note it is also possible to connect a coax socket to the Mini-DIL socket. Shown in the above diagram is a suggestion for connecting a Nortel coax to the Mini-DIL socket. With such an arrangement, it may be possible to have a board compatible with either Mini-DIL, 14-pin DIL, or 4-pin COAX devices

As with any sensitive or high-speed electronic component, to obtain optimum performance from the device, careful attention must be given to the printed circuit board layout.

It is recommended that a double-sided printed circuit board (PCB) with a large, component-side ground plane beneath the receiver must be used. In applications that include many other high-speed devices, a multi-layer PCB is preferred. This permits the placement of power and ground tracks on separate layers, which allows them to be isolated from the signal lines. Multi-layer construction also permits the routing of sensitive traces away from high-level, high-speed signal lines.

Mounting the Device

Nortel's range of Mini-DIL lasers have been designed to be mounted directly to the PCB via plated through holes. Electrical contact and permanent attachment can be achieved by hand or wave soldering the pins to etched tracks on the underside of the PCB. There is no need for the further attachment of heatsinks or clamps.

TYPICAL PERFORMANCE

Laser CW Performance

The Nortel Mini-DIL lasers are available in fibre output powers of 0.1mW, 0.2mW, 0.5mW, 1.0mW, 1.3mW, 1.5mW & 2.0mW. The wavelength ranges available are designed to match the requirements of the ITU/Bellcore specifications. They are:

(i)	1260-1360nm	(-40/+85°C)	for STM 1 short haul / OC3 intermediate reach
(ii)	1274-1355nm	(-40/+85°C)	for STM 4 short haul / OC12 intermediate reach
(iii)	1280-1335nm	(0/85°C)	for STM 1 long haul / OC3 long reach
(iv)	1280-1335nm	(-20/+70°C)	for STM1 long haul / OC3 long reach

Because of the temperature-induced shift of wavelength associated with all Fabry-Perot lasers, it is not possible to use the Mini-DIL described in these application notes for STM4 long haul applications. However the more suitable DFB laser chip is also available in the Mini-DIL package for such requirements. (See LCV113-98 datasheet)

Many of the important laser parameters may be characterised in CW mode. Due to the effects of temperature and ageing, the biasing and modulation levels required to maintain a good extinction ratio may need to be contunuously adjusted via a feedback control loop using the output from the rear facet photodiode (see Circuits for Driving LCV75** Mini-DIL Lasers). This section details some of the primary laser parameters over both temperature and life which need to be considered should designing a laser control circuit be preferred to using that recommended above. Fig 5 shows a typical set of output power vs drive current (L-I) curve.

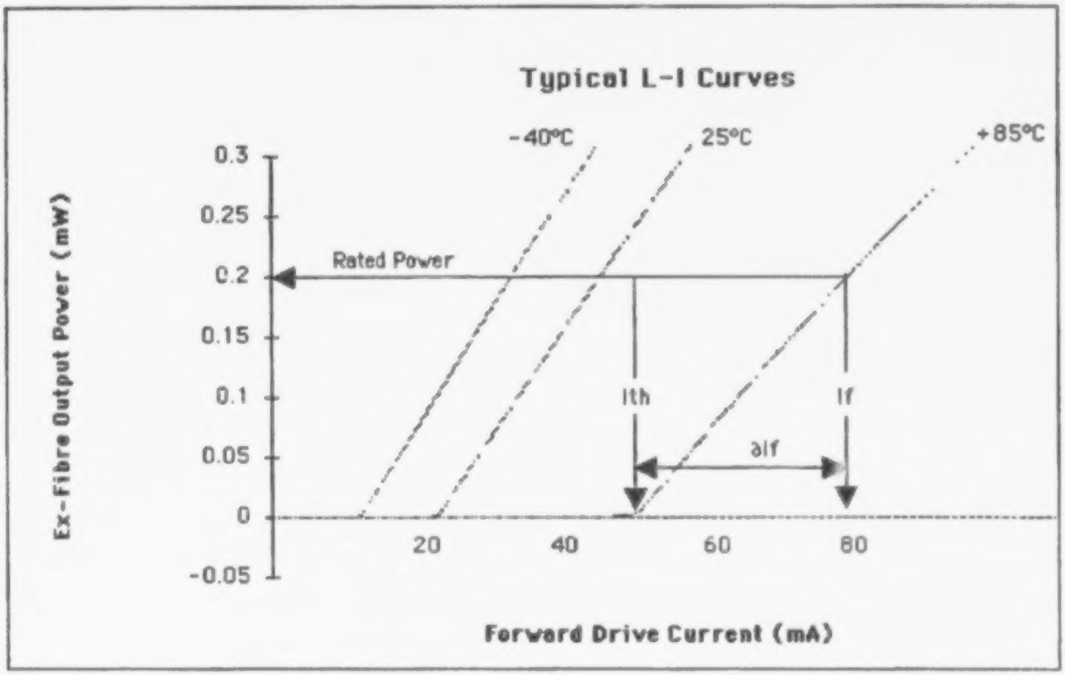


Figure 5 : Variation of Output Power with Temperature

The **threshold current** (Ith), the point beyond which lasing occurs, is strongly temperature dependant. The typical' start-of-life' (SOL) room temperature (25°C) threshold current of the Ridge Waveguide laser used in the Mini-DIL is 18mA. This rises, following a roughly exponential curve to a typical threshold of 35mA @ 70°C and 45mA at 85°C.

Extensive lifetesting (over 5000 hrs accumulated to date) predicts that with an average operating temperature of 60°C over a 15 year lifetime, an end of life (EOL) threshold current at 85°C of 75mA would provide a FIT rate of < 300. Thus if 85°C operation is required over such a lifetime, the control circuitry used must be capable of supplying at least 75mA to achieve threshold.

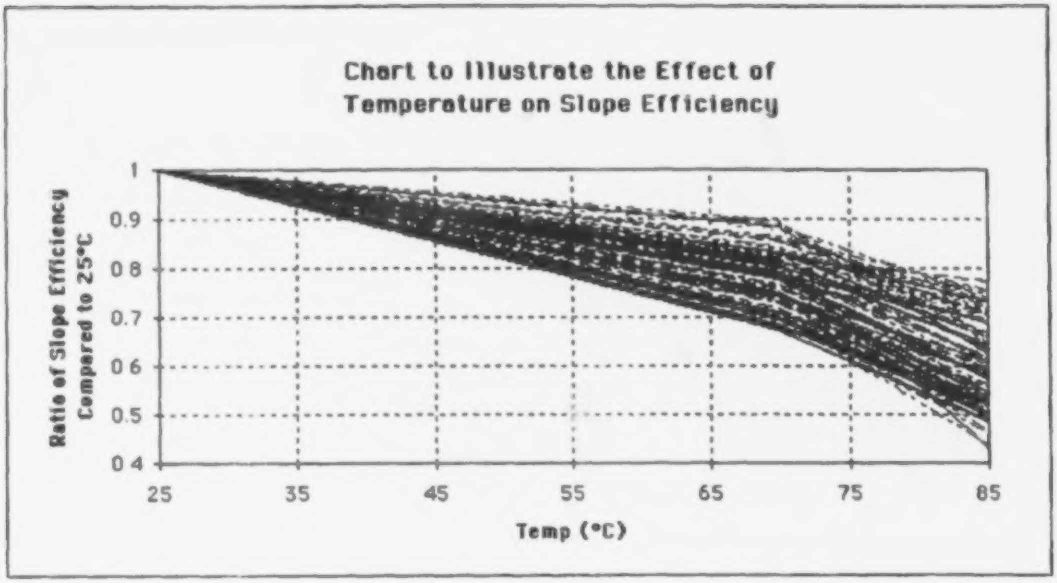


Figure 6 : Effect of Temperature on Slope Efficiency

The **modulation current** or 'drive above threshold' (∂If) is the current required over and above the threshold condition in order to achieve the peak power of the device. For the standard Mini-DIL product, a typical ∂If at room temperature and start of life is 20mA. Depending on the method of controlling the modulation current (and hence extinction ratio), it may be necessary to predict the reduction of efficiency, (and hence increase in ∂If), as temperature is increased. Fig 6 illustrates this effect. At 70°C, the typical increase in ∂If is 20% whilst at 85°C, the typical change is 35%. If 85°C operation is required, a maximum modulation current supply of 50mA (SOL) and 60mA (EOL) is required. Thus a total EOL current supply for 85°C operation at peak power with a FIT rate of < 300 would be 135mA (Ith + ∂If).

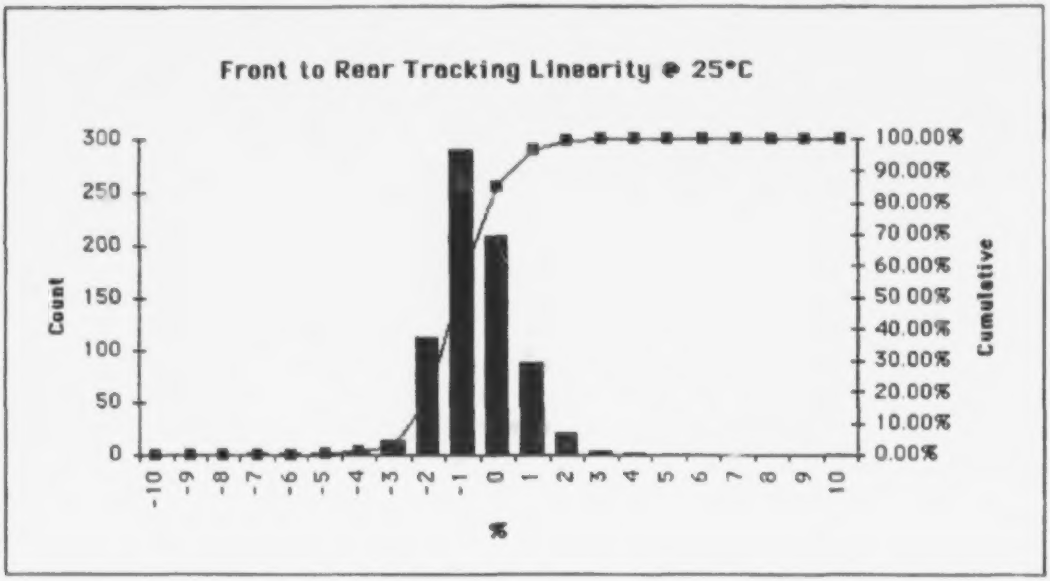


Figure 7 : Front to Rear Tracking

A feedback control loop compensates for changes in the performance of the laser chip. This is done by using the output current (Im) from the rear facet photodiode as an indicator of the light launched into the fibre. (In addition to these changes the ratio of light incident on the photodiode to that launched into the fibre may change. Such changes cannot be compensated for and should be accommodated in the optical link budget). At constant temperature, the front to rear ratio (known as the tracking linearity) is sufficiently constant over a range of drive output powers to be assumed perfect. See fig 7. However, over temperature the variation of coupling requires consideration. Over the temperature range -40/+85°C, despite maintaining a constant rear facet photodiode current, typically ±0.5dB power variations will occur. This effect is known as the tracking error.

Additionally over life, ageing effects have historically caused significant changes in the launched power. These changes have usually been associated with the strain relaxation in the components used in the optical train (i.e. welds between submount and fibre etc.). With comprehensive environmental testing and verification, it has been demonstrated that Nortel's Mini-DIL, due to the inherent stability of its innovative optical bench, requires much lower margins to accommodate such ageing changes. Figs 9 & 10 show plots of output stability during high temperature storage (9000 hrs @ 85°C) and temperature cycling (9000 cycles -40/+85°C). Note 9000 temperature cycles is approximately equivalent to nearly 25 years of exposure to daily temperature maximums of 85°C and nightly minimum's of -40°C. The results indicate typical ageing figures of <0.2 dB whilst the maximum seen is < 0.4 dB. Note that this far exceeds the stringent requirements of Bellcore'983.

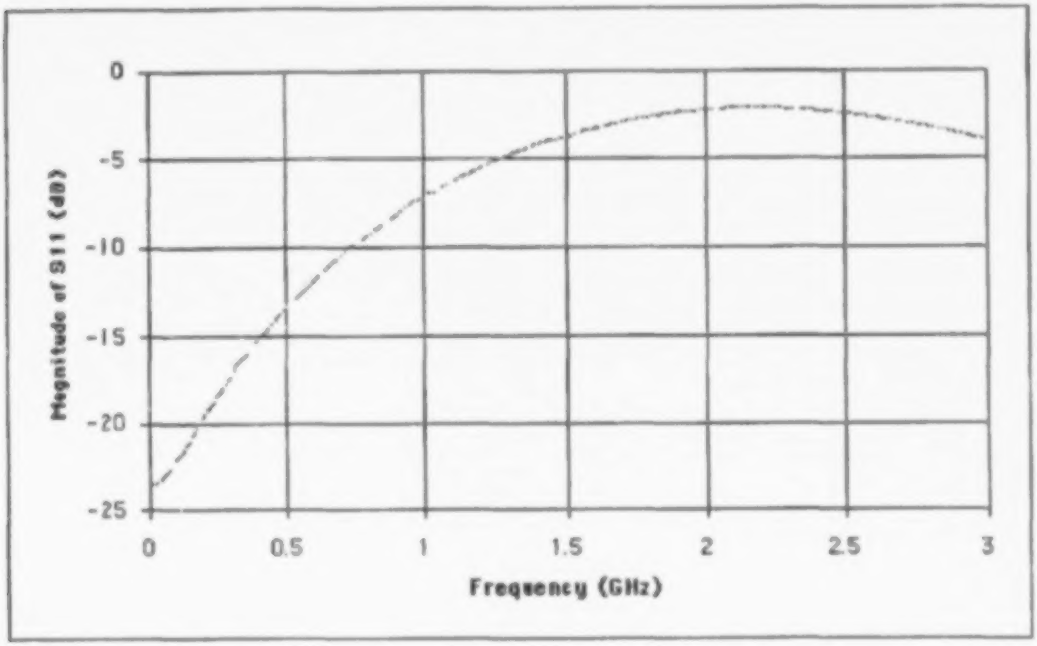


Figure 10 : Reflection Coefficient of RF Signal

Monitor Performance

The rear facet photodiode (monitor) employed in the Mini-DIL is designed to operate both as a mean power monitor and also to provide individual bit monitoring if required. The standard Mini-DIL provides a typical monitor current at the peak output power of 0.4mA. With a reverse voltage of 5V applied, it has a capacitance of < 3pF and provides a dark current of typically 30nA at 85°C and 5nA at 25°C.

The bandwidth of the monitor into a 50Ω circuit is typically 2GHz allowing both the fundamental and the third harmonic of a 622MHz square wave to be detected.

Equivalent Circuit Model

In order to ease SPICE modelling of the Mini-DIL device within the intended control circuitry, an equivalent circuit model of the laser is given in Fig 12 below

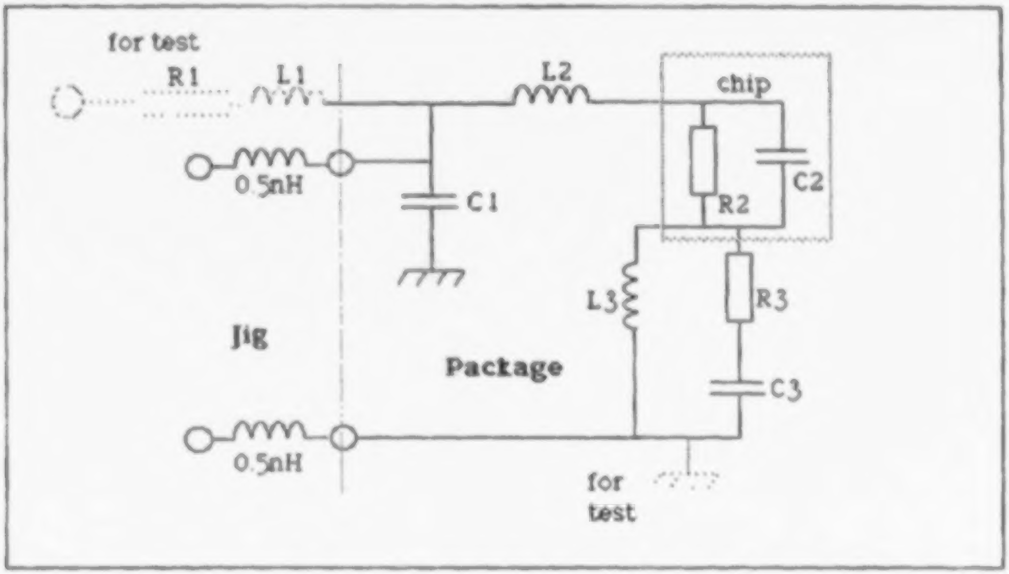
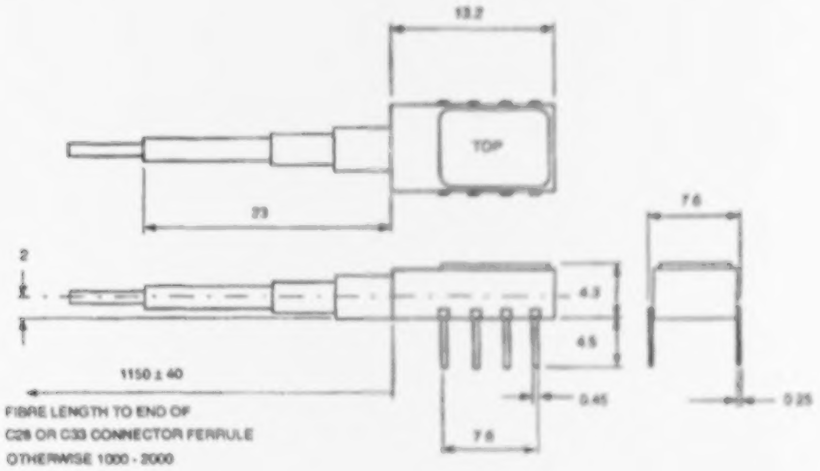

for test
R1
L1
L2
chip
0.5nH
C1
C2
R2
L3
R3
Jig
Package
C3
0.5nH
for
test

Figure 11 : Equivalent Circuit Model

R1	=	51	W
R2	=	6	W
R3	=	110	W
C1	=	0.8	pF
C2	=	16	pF
C3	=	1.5	pF
L1	=	1.35	nH
L2	=	2.8	nH
L3	=	3.2	nH

Note that electrical cross coupling between the laser and the monitor diode has not been measured or modelled.

PACKAGE OUTLINE AND DIMENSIONS


13.2
TOP
23
7.6
2
4.3
4.5
1150 ± 40
0.45
0.25
7.6
FIBRE LENGTH TO END OF
C26 OR C33 CONNECTOR FERRULE
OTHERWISE 1000 - 2000

ASSOCIATED DOCUMENTS

Please note additional information regarding the Mini-DIL can be found in the following documents

1) QR1241: Nortel Qualification report
2) LCV75 Series Nortel Datasheet

APPLICATIONS NOTE

NORTEL
NORTHERN TELECOM

PTAV Series
Mini-DIL Receivers

Nortel plc
Optoelectronics
Paignton
Devon
ENGLAND

AN0035

Issue: 01
Date :April 15th, 1998

GF244/1

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ASSOCIATED DOCUMENTS 8

FEATURES

- Operational Wavelength range 1200nm - 1600nm.
- Silicon-V-groove fibre alignment technology.
- Low noise Amplifier.
- InGaAs PIN.
- Proven reliability and Bellcore TA-NWT-000983 capability.
- Hermetically sealed package.
- 50/125µm cladding mode stripped multimode fibre pigtail.
- Maximum data rate of 622Mbit/s.
- Footprint compatible with 14 pin DIL series.
- Single-ended and differential output options.

APPLICATIONS

- Telecommunications / Data Communications
  - SONET/SDH transmission systems
  - ATM systems

DESCRIPTION

The PTAV series of optical receivers use Nortel's patented Silicon-V-groove fibre alignment technology and provide industry leading stability and exceptional reliability. Nortel's unsurpassed reputation for innovation and quality is embedded in a rugged, hermetically sealed fibre-tailed ceramic package capable of satisfying the requirements of the Bellcore quality specification TA-NWT-000983.

The photodiode is combined with a high performance pre-amplifier with automatic gain control (AGC). Transimpedance values of typically 13kΩ and 5kΩ are achieved for 155MBit/s and 622MBit/s devices respectively (AGC function fully off).

Responsivity is typically >0.85 A/W at the 1300nm wavelength with rise and fall times of <0.5ns .

The PTAV series is fully compliant with TA-NWT-000253 and ITU G.957 and is compatible with Nortel's LCV family of Mini-DIL transmitters.

Suggested Circuit Diagrams

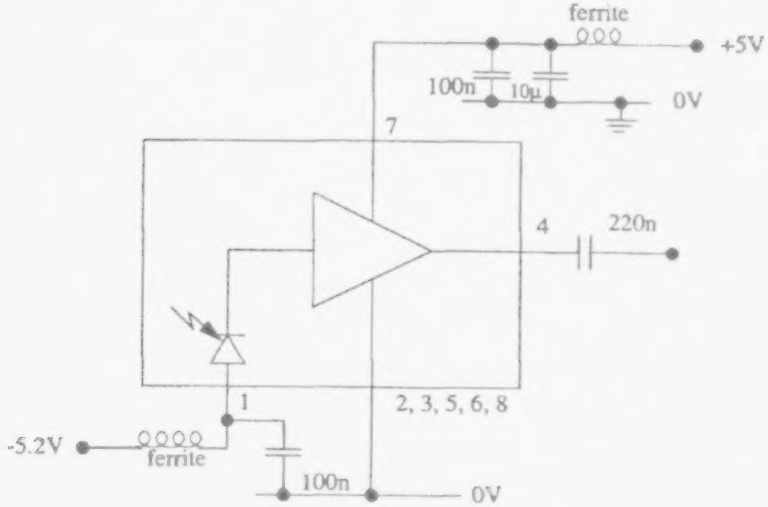

ferrite
+5V
100n
10µ
0V
7
4
220n
1
2, 3, 5, 6, 8
-5.2V
ferrite
100n
0V

Figure 1 : Suggested Circuit Diagram

System Block Diagram

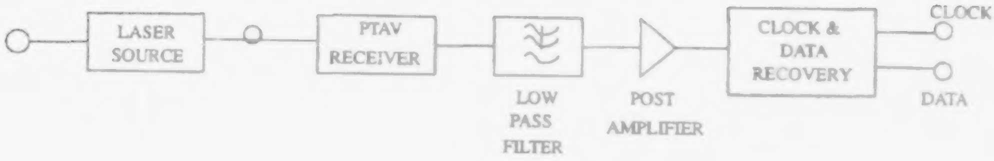

LASER SOURCE
PTAV RECEIVER
LOW PASS FILTER
POST AMPLIFIER
CLOCK & DATA RECOVERY
CLOCK
DATA

Figure 2 : System Block Diagram

The above diagram shows the PTAV receiver within a typical transmission system. The Post Amplifier, Clock Extraction, and Retiming Circuits are normally specified by the systems designer.

Circuit Implementation

In order to achieve acceptable system performance, the overall channel bandwidth must be greater than the Nyquist bandwidth (0.5 x bit rate) and is optimal at approximately 0.6 x bit rate. This is achieved using a 3rd order low-pass filter external to the PTAV matched to 50Ω output impedance

The receiver, filter, and post amplifier circuits should be laid out using standard r.f. electronic techniques. The device should be positioned away from potential sources of radiated emissions, e.g. switchmode power supplies. The filter and post amplifier should be kept as close to the output pin as is physically possible because of the low level of the signal output from the receiver and the high frequencies involved. For reliable electrical contact the receiver pins should be soldered directly into the p.c.b. The length of the pins between the receiver and the p.c.b should be kept at a minimum to ensure good grounding.

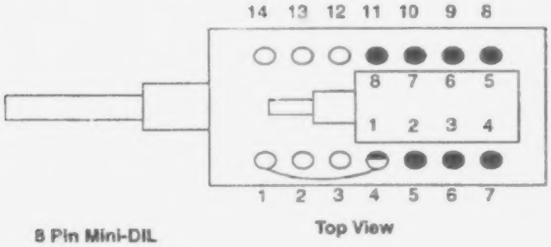
The p.c.b. should be suitable for high frequency signals, incorporating a continuous ground plane.

Each of the power supply rails should incorporate filtering as shown above to minimise EMI issues.

For maximum RFI immunity, the outer surfaces of the ceramic package are metal plated with the metal being at ground potential (connected to pin 2). This includes the underside of the package, and so the user should ensure that vias or any other exposed tracking is not located immediately under the receiver package. This will avoid any possibility of these tracks shorting out to the receiver grounding.

Mini-DIL Board Layouts:-

Figure 3 illustrates the compatibility of the 14 pin DIL and 8 pin Mini-DIL packages.



14 Pin DIL Standard

Pin	1	Photodiode
	2	Case Ground
	3	Case Ground
	4	Not Connected
	5	Case Ground
	6	Case Ground
	7	Output
	8	Case Ground
	9	Case Ground
	10	+ve Supply
	11	Case Ground
	12	Case Ground
	13	Case Ground
	14	Case Ground

8 Pin Mini-DIL

Pin	1	Photodiode
	2	Case Ground
	3	Case Ground
	4	Output
	5	Case Ground
	6	Case Ground
	7	+ve Supply
	8	Case Ground

Figure 3 : 8 Pin / 14 Pin Device Compatibility

The PTAV Mini-DIL has been designed as a drop in replacement for the 14-pin DIL devices and can be placed directly in the 14-pin footprint. Mini-DIL pins 1-8 need to occupy DIL pins 4-11 respectively. A link is required to connect photodiode bias to pin 1. All other connections remain the same.

It is recommended that a double-sided printed circuit board (PCB) with a large, component-side ground plane beneath the receiver is used. In applications that include many other high-speed devices, a multi-layer PCB is preferred. This permits the placement of power and ground planes on separate layers, which allows them to be isolated from the signal lines. Multi-layer construction also permits the routing of sensitive tracks e.g. photodiode bias away from high current, high-speed signal lines.

HANDLING PRECAUTIONS

Flammability

The external materials are a ceramic and metal package, secondary coated fibre and silicon free protective boot. These do not constitute a hazard under normal operation. However, burning of these may result in toxic gas formation.

Electro-Static-Discharge

Like most active semiconductor components, optoelectronic devices are susceptible to damage from electrostatic discharge and surge currents. To reduce this risk to the device, suitable precautions must be taken during system circuit design and during device test and measurement.

In accordance with TR-NWT-000870, the PTAV series devices are Class 2 devices with a HBM (Human Body Model) threshold of 500V. The following precautions should be taken when handling devices:

- Reduce body charge by connecting operators to ground via a non metallic carbon wrist strap.(Resistance of 1 MOhm).
- Ground the measuring and inspecting equipment and the work stations.
- All assembly and test operations should be conducted in a static controlled environment.

Soldering

Device leads may be soldered at a temperature of upto 330°C for a maximum of 5 seconds.

If difficulty is experienced, the leads may be pre-tinned prior to mounting in the pcb.

Storage

Where possible, store optoelectronic devices at a temperature between 10°C and 30°C with a relative humidity of below 40%.

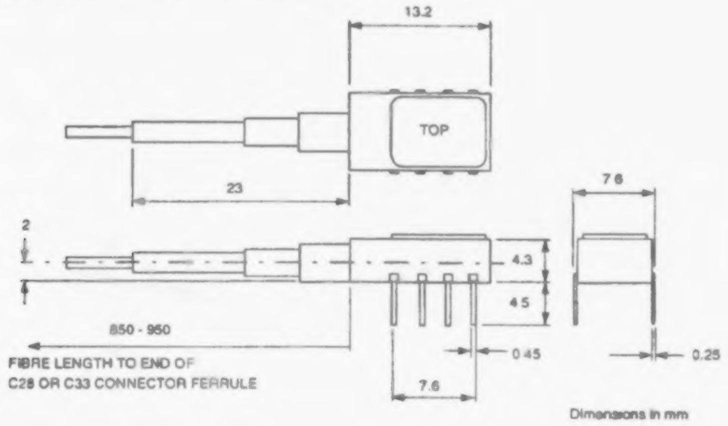
Avoid sudden sharp drops in temperature.

Always keep devices in primary packaging, ideally in an ESD free area.

Fibre

Fibre tail is multimode 50/125um with a 0.9mm Hytrel secondary coat. Please note this is not a ruggedised fibre, (maximum tensile fibre pull 10N). Strain relief is provided at the device end of the fibre in the form of a rubber boot. Appropriate precautions should be taken when handling the fibre tail avoid kinking, twisting or pulling the fibre excessively, and to observe the minimum bend radius of 30mm

PACKAGE OUTLINE AND DIMENSIONS


13.2
TOP
23
7.6
2
4.3
4.5
850 - 950
FIBRE LENGTH TO END OF
C28 OR C33 CONNECTOR FERRULE
0.45
0.25
7.6
Dimensions in mm

ASSOCIATED DOCUMENTS

Additional information regarding the Mini-DIL can be found in the following documents.

1. Mini Dil Receiver Module Qualification Report - QR1313/97.
2. PTAV Series Datasheet.

Agilent Technologies
Innovating the HP Way

LED Eye Safety

Application Note 1109

LED Device Classifications with Respect to AEL Values as defined in the IEC 825-1 Standard and European Norm EN60825-1

Introduction

Several Agilent Technologies (Agilent) Application Briefs (I-008, I-009 and I-015) have been written to explain the impact of recent changes to IEC (International Electrotechnical Commission) 825-1, which added light emitting diodes (LED) device classification to the laser safety standard for eye safety. In this document, light refers to visible and infrared electromagnetic radiation.

Application Brief I-008 gives an explanation of the actions taken by IEC Technical Committee (TC) 76 and CENELEC (European Committee for Electrotechnical Standardization) to correct the overclassification of LED devices during October 1994 through October 1995. During this time period, CENELEC adopted IEC 825-1 as EN60825-1 (EN = European Norm), but also allowed EN60825 (lasers only) to coexist *until March 1, 1996*. This action allowed manufacturers to ship their laser and LED based product under EN60825 (lasers only) until measurement methods and AEL (Accessible Emission Limit) classification of LED devices could be resolved.

During the October 1995 meeting in Sydney, Australia, IEC TC 76 voted to propose the following amendment for IEC 825-1:

1. LEDs will be included for regulation with the same AEL limit calculations and measurement conditions as lasers,
2. There is a choice of two (2) measurement methods:
   a. Measuring distance is fixed at 100 mm, but the diameter of the collecting aperture is variable based upon the apparent source size of the LED/laser.
   b. Measuring distance is variable based on the apparent source size of the LED/laser, but the collecting aperture diameter is fixed at 7 mm.
3. Calculation of apparent source size for multiple or non-circular sources is added.
4. All other rules for labeling and safety interlocks apply equally to LEDs and lasers.

The above measurement methods provide some relief for laser products which were formally measured at 100 mm fixed distance with the light output collected within a 50 mm diameter aperture. CENELEC has adopted the above proposal as Amendment 11 (October 1996) to EN 60825-1.

CENELEC, which adopts many IEC standards as European Norms, extended the date of withdrawal for EN60825 (lasers only) from March 1, 1996 to January 1, 1997, until their own review process was completed. This allowed equipment manufacturers to ship their products under the older EN60825 (lasers only regulated, no LEDs) until January 1, 1997.

Application Briefs I-009 and I-015 address visible LED device classification for Agilent's Optoelectronics Division. This application note will provide the same measurement information and list the AEL classifications for Agilent's CSSD (Communication Semiconductor Solutions Division) products, which cover a range of wavelengths from visible to infrared (IR).

AEL (Accessible Emission Limit) Class Determination

AEL determination for LED and laser based products is done in two steps:

1. Calculate the AEL from the formulas provided in the IEC 825-1 and EN60825-1, Tables 1 - 4.
2. Measure the light output power and compare that actual value to the calculated value.

1. Calculation of AEL

Examples of visible LED AEL calculations are well covered in Agilent Technologies Application Brief I-015. The examples immediately below show the calculated AEL Class 1 limits for small sources for two common infrared wavelengths: 820 nm and 1300 nm.

Exposure time for LED based communication and illumination applications defaults to 100 seconds. Using this value, refer to Table 1 of IEC 825-1/EN60825-1. Find the appropriate wavelength category and extract the AEL Class 1 formula:

Example 1:
For 820 nm, 100 seconds

Limit = $7 \times 10^{-4}\ t^{0.75} C_4 C_6$ J

$C_4 = 10^{0.002(\lambda - 700)} = 1.7378$
$C_6 = 1$ for $\alpha < \alpha_{min}$

where J is the energy in Joules, λ is the wavelength in nanometers (nm), and t is the time in seconds (use the default value of 100). For a discussion of α_{min}, refer to section 2 below.

Insert the values and calculate the AEL Class 1 limit in Joules:

Limit =
$7 \times 10^{-4}\ 100^{0.75}\ (1.7378)\ (1)$ J

Limit = 0.0385 Joules

Convert Joules to milliwatts by dividing by 100 seconds to obtain watts, and multiplying by 1000 to obtain milliwatts (mW):

Limit = 0.385 mW

Example 2:
For 1300 nm, 100 seconds

Limit = $3.5 \times 10^{-3}\ t^{0.75} C_6 C_7$ J
$C_7 = 8$
$C_6 = 1$ for $\alpha < \alpha_{min}$

where J is the energy in Joules, λ is the wavelength in nanometers (nm), and t is the time in seconds (use the default value of 100). For a discussion of α_{min}, refer to section 2 below.

Insert the values and calculate the AEL Class 1 limit in Joules:

Limit = $3.5 \times 10^{-3}\ 100^{0.75}\ (1)(8)$ J
Limit = 0.8854 Joules

Limit = 8.854 mW

For devices with an apparent source size of less than 1.1 mm, for 820 nm, the **AEL Class 1** limit is **0.385 mW**; for 1300 nm, the **AEL Class 1** limit is **8.854 mW**.

A third example is for an emitter with larger source size. An infrared lamp at 875 nm wavelength has an apparent source size of 3.1 mm. The calculation proceeds similarly:

Example 3:
For 875 nm, 100 seconds

Limit =
$7 \times 10^{-4}\ t^{0.75} C_4 C_6$ J

$C_4 = 10^{0.002(\lambda - 700)} = 2.2387$
$C_6 = \alpha / \alpha_{min} = 31/11 = 2.8182$

(α_{max} = 100 milliradians > α =
31 milliradians > α_{min})

Insert the values and calculate the AEL Class 1 limit in Joules:

Limit =
$7 \times 10^{-4}\ 100^{0.75}\ (2.2387)\ (2.8182)$ J

Limit = 0.1397 Joules

Again, converting Joules to milliwatts (dividing by the time, 100 seconds), the **AEL Class 1 limit is:**

1.397 mW

The examples above were for the lowest AEL Class, Class 1. It is one of a number of classes with different interpretations and restrictions. Calculations for Class 2, Class 3A and Class 3B, corresponding to the Class 1 examples above, can be made using the information in Tables 2, 3 and 4 in the IEC and CENELEC documents. These are summarized in Table 1 on the following page.

2. Measurement of the Light Output Power

Under the new proposed amendment to IEC 825-1 (and CENELEC EN60825-1, Amendment 11) the measurement conditions are a function of apparent source size. The amendment defines the measurement conditions in terms of the angle subtended by the source at a distance of 100 mm. How to measure apparent source size is not clearly stated. However, the standard implies the following criterion be used:

> Determine the diameter of a circular aperture, which, placed in the plane of emission, would

Table 1.

Class	Interpretation	Requirements
1	Safe under reasonably foreseeable conditions of operation	Explanatory label on product (optional); must declare class in customer information.
2	Eye protection is normally afforded by aversion responses including the blink reflex. (400-700 nm only)	Warning label and Class 2 explanatory label on product and in customer information.
3A	Safe for viewing with the unaided eye. Direct intrabeam viewing with optical aids may be hazardous.	Warning label and Class 3A explanatory label on product and in customer information.
3B	Direct intrabeam viewing is always hazardous. Viewing diffuse reflections is normally safe.	Warning label and Class 3B explanatory label on product and in customer information.
4	Capable of producing hazardous diffuse reflections	Warning label and Class 4 explanatory label on product and in customer information.

allow 63.2% (1 – 1/e, where e is the base of natural logarithms approximately equal to 2.71828) of the output to pass.

Since many LEDs have a lens structure, the apparent source size may be determined from an optical image of the source.

Given the apparent source size, **a** (in mm), the angular subtense, α, of the source at 100 mm distance is given by :

$\alpha = 1000 \times [2 \times \arctan((a/2)/100)]$ milliradians (mr)

$\alpha \sim 1000 \times [a/100]$ mr

Arctan is the inverse tangent or arc tangent function, expressed in radian angular measure; **x** denotes multiplication. A radian (or milliradian) is a measure of angle; an angle of 180 degrees is equivalent to an angle of π radians.

Given the angular subtense, the measurement distance, **r**, and corresponding aperture diameter, **d**, (with x denoting multiplication) are determined by:

$\mathbf{r} = 100$ mm
$\mathbf{d} = 7$ mm
for $\alpha > 100$ mr

$\mathbf{r} = 100 \times \sqrt{(\alpha + 0.46\ \text{mr})/\alpha_{max}}$ mm
$\mathbf{d} = 7$ mm
for $100\ \text{mr} \geq \alpha > 1.5$ mr

$\mathbf{r} = 100$ mm
$\mathbf{d} = 50$ mm
for $\alpha \leq 1.5$ mr

where α_{max} is 100 mr for all these calculations. $\alpha = 100$ mr corresponds to a source with **a**~10 mm; $\alpha = 1.5$ mr, corresponds to a source with **a**~ 0.15 mm.

The distance **r** can be expressed in terms of apparent source size, **a**, instead of angular subtense, α. Substituting 1000**a** /100 for α, and 100 milliradians for α_{max}:

$\mathbf{r} = 100$ mm
$\mathbf{d} = 7$ mm
for $\mathbf{a} > 10$ mm

$\mathbf{r} = 100 \times \sqrt{a/10 + 0.0046}$ mm
$\mathbf{d} = 7$ mm
for $10\ \text{mm} \geq \mathbf{a} > 0.15$ mm

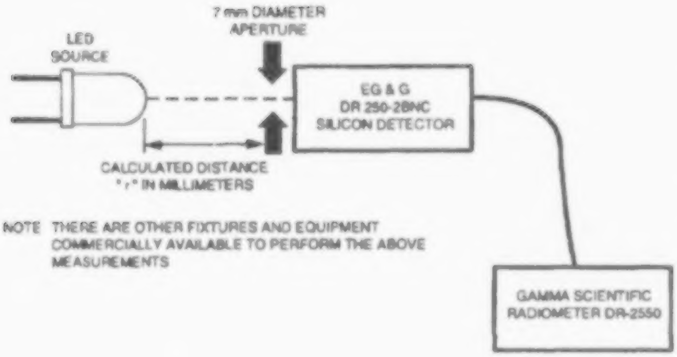
$\mathbf{r} = 100$ mm
$\mathbf{d} = 50$ mm
for $\mathbf{a} \leq 0.15$ mm

For the 3.1 mm source in Example 3 above, the measurement distance, **r**, would be **56.1 mm.**

α_{min}, referenced in the preceding section, is dependent on the exposure time. However, for the default case of 100 seconds, α_{min} takes on a value of 11 mr. This corresponds to an apparent device size of 1.1 mm. α_{min} is the smallest angular subtense that the eye can discern; smaller sources appear to be at least this large. Because of involuntary eye and head movements, in 100 seconds (actually, any time greater than 10 seconds) all small sources are "smeared" into a source which appears to be at least 11 mr in apparent angular subtense.

3. Measurement Setup

In order to perform the light output


7 mm DIAMETER APERTURE
LED SOURCE
EG & G DR 250-2BNC SILICON DETECTOR
CALCULATED DISTANCE "r" IN MILLIMETERS
GAMMA SCIENTIFIC RADIOMETER DR-2550

NOTE THERE ARE OTHER FIXTURES AND EQUIPMENT COMMERCIALLY AVAILABLE TO PERFORM THE ABOVE MEASUREMENTS

Figure 1.

power measurement, the following equipment is needed:

1. Radiometer
2. Detector capable of sensing light at the wavelength of the LED
3. 7 mm circular aperture
4. Variable positioner

Procedure:

1. Determine the measurement distance from the formula in section 2.
2. Place the aperture (and detector) at the calculated distance from the LED source, or the nearest optical surface if the LED is behind a window or lens.
3. Turn on the radiometer and detector.
4. Turn on the LED and align it to provide the highest radiometer reading (usually at or near the "head-on" alignment, along the optical axis).
5. Read the detector current (in amps, or milliamps, or microamps) from the radiometer.
6. Using the detector calibration chart or table, (provided by the detector manufacturer), find the detector responsivity which corresponds to the LED peak wavelength.
7. Calculate the power in watts using the following formula:

   Power (watts) =
   [Detector Current (amps)] ÷
   [Responsivity (amps/watt)]

8. Compare the measured power from Step 7 to the calculated AEL Class 1 limit. If the measured power is greater than the Class 1 limit, the actual classification is greater than Class 1 (probably Class 2 for visible LEDs, Class 3A for infrared LEDs). To determine the actual Class, refer to IEC 825-1 for the formulas. If, however, the measured power is less than the Class 1 limit, the source is operating as Class 1.

4. Fault Conditions

Quoting from IEC 825-1, Section 8 Tests, 8.1 General:

"Tests during operation shall be used to determine the classification of the product. Tests during operation, maintenance and service shall also be used as appropriate to determine the requirements for safety interlocks, labels and information for the user. Such **tests shall be made under each and every reasonably foreseeable single fault condition.**"

Thus, a manufacturer must determine what reasonably foreseeable single fault conditions may occur. Note the standard does not say "all possible single fault conditions." However, it is recommended that any single faults determined not to be reasonable by the manufacturer be investigated.

For manufacturers incorporating a procured part or module in their final products, two sets of single fault conditions must be considered:

1. Procured part single fault.
2. Failure of the final product exclusive of the targeted procured part which causes the procured part to exceed the AEL class limit.

For 1., the procured part can best be investigated for single fault conditions by the manufacturer, who must inform the customer.

For 2., the final manufacturer must determine the fault conditions (departure from normal operation) which can occur external to the procured part. Secondly, the impact of these fault conditions must be determined.

5. Classification

Considering the worst fault under 1. and 2. above, the final manufacturer must use this condition to determine the AEL Classification.

Quoting from IEC 825-1 Section 9 Classification, 9.3 Classification procedures:

"It is the responsibility of the manufacturer or his agent to provide correct classification of a laser [or LED] product. The product shall be classified on the basis of that combination of output power(s) and wavelength(s) of the accessible laser [or LED] radiation over the full range of capability during operation at any time after manufacture which results in its allocation to the highest appropriate class."

This is not in full agreement with IEC 825-1 Section 8 Tests, 8.1 General:

"Tests during operation shall be used to determine the classification of the product. Tests during operation, maintenance and service shall also be used as appropriate to determine the requirements for safety interlocks, labels and information for the user. Such tests shall be made under each and every reasonably foreseeable single fault condition."

and with IEC 825-1 Section 1 Scope and object, 1.1 Scope:

"... classification by the manufacturer ... shows that the emission level does not exceed the AEL of Class 1 under all conditions of operation, maintenance, service and failure..."

All statements considered, it is recommended that classification be done under the worst reasonable single fault for **operation only. Maintenance and service** conditions shall be added to the operation conditions to determine requirements for interlocks (not treated here, and it is unlikely any LED products would require this; refer to IEC 825-1 for more information), labeling and user information.

6. Labeling and Written Declaration

Quoting from IEC 825-1 Section 5, Labeling:

"5.1 General Each laser [or LED] product shall carry label(s) in accordance with the following clauses. The labels shall be permanently fixed, legible, and clearly visible during operation, maintenance or service, according to their purpose. They shall be positioned so that they can be read without the necessity for human exposure to laser [or LED] radiation in excess of the AEL for Class 1. Text borders and symbols shall be black on a yellow background except for Class 1 where this colour combination need not be used.

"If the size or design of the product makes labelling impractical, the label should be included with the user information or on the package.

"5.2 Class 1 Each Class 1 laser [or LED] product shall have affixed an explanatory label (figure 15) bearing the words:

CLASS 1 LASER [or LED]
PRODUCT

or, at the discretion of the manufacturer, the same statement shall be included in the information for the user."

"5.3 Class 2 Each Class 2 laser [or LED] product shall have affixed a warning label (figure 14) and an explanatory label (figure 15) bearing the words:

LASER [or LED] RADIATION
DO NOT STARE INTO BEAM
CLASS 2 LASER [or LED]
PRODUCT

"5.4 Class 3A Each Class 3A laser [or LED] product shall have affixed a warning label (figure 14) and an explanatory label (figure 15) bearing the words:

LASER [or LED] RADIATION
DO NOT STARE INTO BEAM
OR VIEW DIRECTLY WITH
OPTICAL INSTRUMENTS
CLASS 3A LASER [or LED]
PRODUCT

Agilent Technologies
Innovating the HP Way

AEL Classification of OCD Products based on proposed IEC 825-1 amendment.

Device Model Number	Wavelength (nm)	AEL Class 1 Limit (mW)	Total Output Power (mW)	IEC 825-1 AEL Class
HFBR-0300	1300	8.854	0.079	1
HFBR-0400	820	0.385	0.199	1
HFBR-13X2	1300	8.854	0.079	1
HFBR-14X4	820	0.385	0.199	1***
HFBR-15X1	660	0.221	0.174	1
HFBR-15X2	660	0.221	0.355	1*
HFBR-15X3	660	0.221	0.355	1*
HFBR-15X4	660	0.221	0.355	1*
HFBR-15X6	660	0.221	0.204	1
HFBR-15X7	650	0.221	1.000	1*
HFBR-1528	650	0.221	1.122	1*
HFBR-5103	1300	8.854	0.039	1
HFBR-5104	1300	8.854	0.063	1
HFBR-5105	1300	8.854	0.039	1
HFBR-5106	1300	8.854	0.039	1
HFBR-5107	820	0.385	0.063	1
HFBR-5111	1300	8.854	0.039	1
HFBR-5112	1300	8.854	0.039	1
HFBR-5113	1300	8.854	0.039	1
HFBR-5203	850	0.442	0.063	1
HFBR-5204	1300	8.854	0.039	1
HFBR-5205	1300	8.854	0.039	1
HFBR-5207	1300	8.854	0.039	1
HFBR-5301	1300	8.854	0.039	1
HFBR-5302	1300	8.854	0.039	1
HFBR-5320	1300	8.854	0.039	1
HSDL-4220	875	1.397	1.461	3A**
HSDL-4230	875	2.550	1.766	1

* The classification of parts marked 1* appear from the table to be above Class 1 However, devices measured under the appropriate calculated conditions show operation to be below the AEL Class 1 limit

** The classification for the part marked 3A** would be Class 3A for a maximum-efficiency part driven at the maximum rated current Decreasing the current slightly would change the Class 3A to Class 1, so the final determination of classification is dependent on the design of the equipment.

*** HFBR-14X4 used with fibers of core diameters up to 100-µm is Class 1. However, when used with fiber of 200 µm (0 4 numerical aperture) core diameter, drive currents below 45 mA will give Class 1 operation. Driving the HFBR-14X4 with a 200-µm core diameter fiber at currents above 45 mA may result in Class 3A operation

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Agilent Technologies
Innovating the HP Way

Inexpensive 20 to 160 MBd Fiber-Optic Solutions for Industrial, Medical, Telecom, and Proprietary Data Communication Applications

Application Note 1123

Introduction

Low-cost fiber-optic data-communication links have been used in place of copper wire in numerous industrial, medical and proprietary applications. The fiber-optic transmitters and receivers shown in this publication can be used in a wide range of applications that convey encoded serial data provided by off-the-shelf, large-scale, mixed-signal integrated circuits such as the AMD TAXIchip ™, the Cypress HOTLink ™ or the PMC Sierra S/UNI-LITE ™. Byte-to-light solutions can be quickly implemented when these off-the-shelf serializer/deserializer circuits are combined with the fiber-optic transceivers described in this publication. Complete +5 V ECL (PECL)-compatible digital fiber-optic transceivers are presented in this application note. These complete solutions include the schematic, printed circuit artwork and material lists, so that users of this low-cost optical technology will not need to do any analog design. Designers interested in the recommendations contained in this publication are encouraged to imbed these reference designs in their products, and various methods for electronically down-loading these reference designs are described.

Why Use Optical Fibers?

Although copper wire is an established technology that has been successfully used to transmit data in a wide range of industrial, medical and proprietary applications, it can be difficult or impossible to use in numerous situations. By using differential line receivers or optocouplers, copper wires can be used to transmit data in applications where the reference or ground potentials of two systems are different, but care must be taken not to corrupt the data with noise induced into the metallic conductors or shields by adjacent power lines or differences in ground potential. Unlike copper wires, optical fibers do not require rigorous grounding rules to avoid ground loop interference, and optical transmission lines do not need termination resistors to avoid reflections. Optical transceivers and cables can be designed into systems so that they will survive lightning strikes that would normally damage metallic conductors or wire input/output (I/O) cards. In essence, fiber-optic data links are used in electrically noisy environments where copper wire fails.

In addition to all of these inherent advantages, there are two other reasons why optical fibers are beginning to replace copper wires. The first reason is that optical connectors suited for field installation with minimal training and simple tools are now available. The second reason is that when using plastic optical fiber (POF) or hard clad silica (HCS) fiber, the total cost of the data communication link is roughly the same as when using copper wires.

Communication Protocols and Optical Data Links

Many existing serial communication protocols were developed for use with copper wire. At data rates below 30 Mbits/second, copper wire has routinely been used with differential line receivers or optocouplers that can sense the dc component of binary data communication signals. This type of serial data is often called "arbitrary duty factor" data because it can remain in the logic "1" or logic "0" state for indefinite periods of time. Arbitrary duty factor data has an average value, which can instantaneously be anywhere between 0 percent and 100 percent of the binary signal's amplitude, or in other words, arbitrary duty factor data contains dc components. Communication protocols that were developed specifically for use with copper wire often require an optical receiver that is dc coupled or capable of detecting if the data is changing from a high-to-low or low-to-high logic state, that is, the receiver needs to be an edge detector. At relatively modest data rates between zero and 10 Mbits/sec it is possible to construct dc coupled TTL-compatible fiber-optic receivers. The Agilent HFBR-2521 is a TTL-compatible, dc-to-5 Mbit/sec receiver, and the HFBR-2528 is a dc-to-10 Mbit/sec CMOS or TTL-compatible receiver. Additional information about dc-to-5 Mbit/sec applications can be found in Hewlett-Packard AN-1035, and applications support for dc-to-10 Mbit/sec applications can be obtained by reading AN-1080. This application note focuses on optical data communication links that operate at much higher data rates and much greater distances than achievable with the dc-coupled or edge-detecting fiber-optic receivers. The optical transceivers shown in this application note are intended for use with parallel data that has been replaced by serialized encoded symbols. When encoding is used, the average value of the serial data is equal to approximately 50 percent of the serialized data's amplitude. If your communication system sends unencoded or burst-mode data where the average value of the serial data can arbitrarily be anywhere between 0 percent to 100 percent of the binary signal's amplitude, please refer to the solutions provided in Agilent Application Note 1121.

Advantages of Encoded Run-Limited Data

As the data rate of a digital communication link increases, the reasons for encoding the raw data become more compelling. When data is encoded, the original data bits are replaced with a different group of bits known as symbols. The symbols that replace the original data are selected so that the encoded data is compatible with simple, highly sensitive, ac-coupled fiber-optic receivers. Encoding enables the construction of optimal fiber-optic receivers which are limited by the random noise inherent in the receiver's first amplifier stage. Noise-limited ac-coupled receivers can provide very low error rates when used with long optical fibers, or can be useful in applications that utilize optical splitters having large amounts of fixed optical losses.

Data is encoded to prevent the digital information from remaining in one of the two possible logic states for an indefinite period of time. When data is encoded, a characteristic known as the "run limit" is established. If data is not changing, the run limit defines how much time may pass before the encoder inserts a transition from one logic state to another. The run length, or run limit of the encoder, is the number of symbol periods that are allowed to pass before the encoder changes logic state. Encoders usually force the encoded data to have a 50 percent duty factor, or they restrict the duty factor to a limited range, such as 40 percent to 60 percent. When data is encoded, the fiber-optic receiver can be ac-coupled as shown in Figure 1. Without encoding, the fiber-optic receiver would need to detect dc levels, or edges, to determine the proper logic state during long periods of inactivity when there are no changes in the transmitted data. AC-coupled fiber-optic receivers tend to be lower in cost, are much easier to design, provide better sensitivity and contain fewer components than their dc-coupled counterparts.

No matter which type of fiber-optic media is used, the receiver's PIN pre-amplifier should be ac-coupled to a limiting amplifier and comparator as shown in Figure 1. Direct coupling decreases the sensitivity of a digital fiber-optic receiver, since it allows low-frequency flicker noise from transistor amplifiers to be presented to the receiver's comparator input. Any undesired signals coupled to the comparator will reduce the signal-to-noise ratio at this critical point in the circuit, and reduce the sensitivity of the fiber-optic receiver.

Another problem associated with direct-coupled receivers is the accumulation of dc offsets. With direct coupling, the receiver's gain stages amplify the effects of undesirable offsets and voltage drifts due to temperature changes. These amplified dc offsets will eventually be applied to the comparator and result in reduced sensitivity of the fiber-optic receiver. The dc offset at the comparator can be referred to the optical input of the receiver by dividing by the receiver's gain. This division refers the dc offset at the comparator to the receiver input where it appears as a change in optical power that must be exceeded before the receiver will switch logic states. Problems with

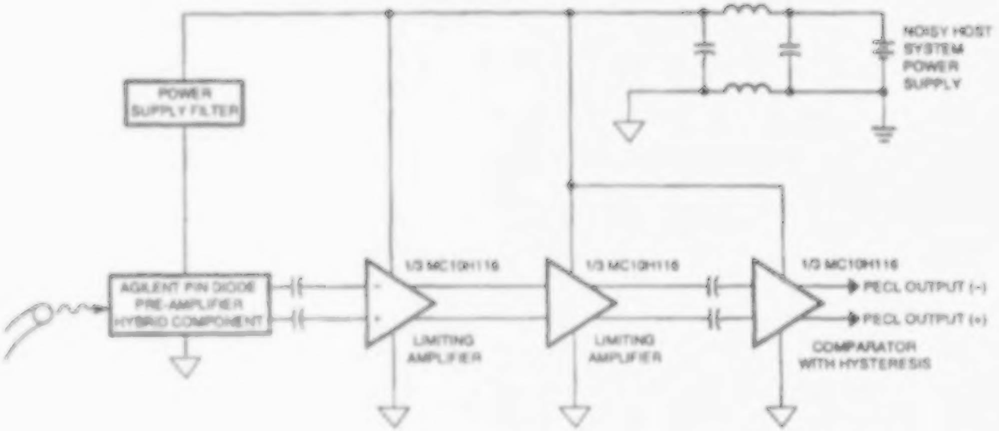


Figure 1. Simplified +5 Volt ECL (PECL-compatible) Fiber-optic Receiver Block Diagram for High Data Rate Applications with Encoded Data

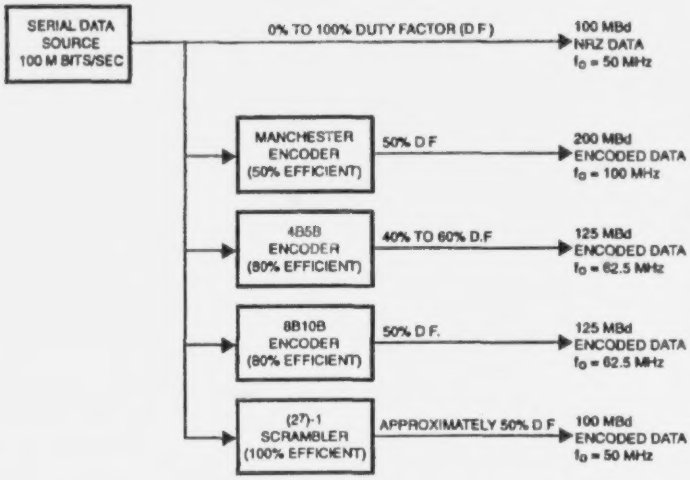
dc drift can be avoided by constructing the receiver as shown in Figure 1.

Encoding has other advantages. Encoding merges the data and clock signals in a manner that allows a timing-recovery circuit to reconstruct the clock at the receiver end of the digital data link. This is essential because fiber-optic links can send data at such high rates that asynchronous timing-recovery techniques, such as over-sampling, are not very practical. Synchronous detection can be accomplished without encoding, but the clock signal required to synchronously detect the data would need to be sent via a second fiber-optic link. Separate transmission channels for data and clock signals are usually avoided due to cost, but problems with time skew between the data and clock can also arise if separate fibers are used to transmit these signals.

Characteristics of Encoders

A Manchester encoder replaces each bit with two symbols. For instance, when using Manchester code a logic "1" is replaced by a ("1", "0") symbol, and a logic "0" is replaced by a ("0", "1") symbol. Manchester code is not very efficient since it doubles the fundamental frequency of the data by substituting two symbols for each bit transmitted. Block substitution codes such as 4B5B replace four bit nibbles of data with a five bit symbol. Other popular block substitution codes are also used. A 5B6B encoder replaces each group of five bits with a six bit symbol and an 8B10B encoder replaces an entire eight bit byte with 10 symbols. Block substitution codes encode the data more efficiently. If Manchester code is used to transmit data at 100 Mbits/second, the fiber-optic channel must be capable of passing 200 million symbols/second. Baud (Bd) is expressed in units of symbols/second, thus the Manchester encoder in this example requires a serial data link that can work at 200 MBd. If the less efficient Manchester encoder is replaced by a more efficient 4B5B encoder, the same 100 Mbit/second data can be sent at a signaling rate of 125 MBd. In binary transmission systems, the maximum fundamental frequency of the data is half the symbol rate expressed in Bd. When a Manchester encoder is used to send 100 M bit/second data, at a symbol rate of 200 MBd, the maximum fundamental frequency of the data is 100 MHz. By using a 4B5B encoder, the same 100 Mbit/second data can be transmitted at 125 MBd, at a maximum fundamental frequency of 62.5 MHz.

The minimum fundamental frequency that the fiber-optic link must pass is also determined by the encoding rule chosen. The run limit of the encoder determines the maximum number of symbol periods that the encoder will allow before it forces a transition,


SERIAL DATA SOURCE 100 M BITS/SEC
0% TO 100% DUTY FACTOR (D F)
100 MBd NRZ DATA f_0 = 50 MHz
MANCHESTER ENCODER (50% EFFICIENT)
50% D F
200 MBd ENCODED DATA f_0 = 100 MHz
4B5B ENCODER (80% EFFICIENT)
40% TO 60% D.F
125 MBd ENCODED DATA f_0 = 62.5 MHz
8B10B ENCODER (80% EFFICIENT)
50% D F.
125 MBd ENCODED DATA f_0 = 62.5 MHz
(2^7)-1 SCRAMBLER (100% EFFICIENT)
APPROXIMATELY 50% D F
100 MBd ENCODED DATA f_0 = 50 MHz

NOTE THAT f_0 IS THE MAXIMUM FUNDAMENTAL FREQUENCY OF THE ENCODED DATA
THE MINIMUM FUNDAMENTAL FREQUENCY OF THE ENCODED DATA IS DETERMINED BY THE ENCODER'S RUN LIMIT

Figure 2. Attributes of Encoding

thus the encoder's run limit determines the minimum fundamental frequency of the encoded data. Manchester code will allow only two symbol periods to pass without a transition. As many as three symbol times without a transition will be allowed by the 4B5B encoder used in the AMD TAXIchip™.

Figure 2 illustrates the attributes of various encoding techniques. Figure 2 shows that as encoder efficiency improves, the bandwidth needed in the fiber-optic communication channel is reduced. Conversely, for a fixed communication channel bandwidth the number of bits/second that can be transmitted will increase as encoder efficiency improves.

Off-the-Shelf Parallel-to-Serial and Serial-to-Parallel Converter Chips

Large scale integrated physical layer circuits (PHY chips) such as the AMD TAXIchip, CYPRESS HOTLink and PMC Sierra S/UNI LITE do more than encode the data. Modern PHY chips provide the digital and analog functions needed to transform the parallel data found in virtually all parallel architecture computer-based systems to the serial data needed for transmission via an optical fiber communication link. The mixed-signal LSI chip at the transmitting end of the fiber-optic link synthesizes a high-frequency clock from the host system's byte-rate clock, multiplexes parallel TTL data to serial data and provides the control words and synchronizing signals needed to manage a serial data communication link. The mixed-signal LSI chip at the receiving end contains a phase-locked loop to recover the clock signal imbedded in the received serial data, a decoder to strip off the encoding, plus a demultiplexer that converts the serial data and control signals back to a parallel TTL output. The high-speed serial inputs and outputs of most PHY chips are compatible with +5V ECL (PECL) logic. Since the fiber-optic transceiver described in this application note has PECL-compatible inputs and outputs, it can be easily combined with the TAXIchip, HOTLink or S/UNI-LITE chips to build byte-to-light communication systems.

Only One Transceiver Design Needed

This application note will show that various Agilent LED transmitters and PIN-diode pre-amplifiers can be used in a single transceiver design that can be electronically down-loaded and imbedded into a wide range of products to provide very low-cost data communication solutions. Without changing the form-factor or printed circuit design, the transceiver shown in this publication can be populated with components that can send digital data via plastic optical fiber, hard clad silica fiber, multimode glass fiber or single-mode glass fiber. When these schematics and printed circuit artworks are electronically imported and imbedded into your system, the same inexpensive transceiver circuit can be used with a wide variety of fiber-optic cables so that one design can be used to address an extremely wide range of data communication applications.

Distances Achievable at Data Rates up to 160 MBd

The simple transceivers recommended in this application can be used to address a very wide range of distances, data rates and system cost targets. The maximum distances allowed with various types of optical fiber and Agilent's wide range of fiber-optic transceiver components are shown Table 1. No transmitter or receiver adjustments are needed when using fiber cable lengths that vary from virtually zero length up to the maximum distances specified in Table 1.

Simple PECL-Compatible LED Transmitter

A high-performance, low-cost PECL-compatible transmitter is shown in Figure 3. This transmitter recommendation looks deceptively simple but has been highly developed to deliver the best performance achievable with a wide range of Agilent LED transmitters. The recommended transmitter is also very inexpensive since the 74ACTQ00 gate that modulates the current of the various LED transmitters can typically be obtained for under $0.40. No calculations are needed to determine the passive component needed when using various Agilent LEDs and various optical fibers. Simply use the recommended component values shown in Table 2, and the transmitter shown in Figure 3 can be used to address a wide range of applications.

Simple High-Sensitivity PECL-Compatible Receiver

A very simple PECL-compatible receiver with excellent sensitivity and suited for a wide range of applications is shown in Figure 4. The receiver in Figure 4 is optimal for operation at any data rate between 20 and 160 MBd. A single low-cost 10H116 ECL line receiver is used to amplify and digitize the output of the Agilent PIN diode pre-amp component, which functions as the receiver's first stage. The third section of the 10H116 integrated circuit is configured to provide hysteresis, so that when no light is applied to the receiver's optical input the digital output of the receiver will not chatter. The simple low-cost circuit shown in Figure 4 provides excellent sensitivity, adequate for many applications. Some data communication protocols however require that the optical receiver provide an optical link status flag (also known as signal detect) that switches state when received power is low, or the optical fiber is disconnected. An alternative receiver that provides this signal detect function is shown in Figure 5. Both receiver circuits have similar relationships between sensitivity, and error rate, since the random noise from the Agilent PIN diode pre-amp used in the first stage has a dominant effect upon the receiver's performance.

Table 1

LED Transmitter Component Part # and Wavelength	Receiver Component Part # and Wavelength	Fiber Diameter Type	Maximum Distance at 160 MBd with the transceiver circuits recommended in this publication
HFBR-15X7 650 nm	HFBR-25X6 650 nm	1 mm plastic step index NA = 0.35	50 meters with the transceiver in Fig. 7 or Fig. 8
HFBR-15X7 650 nm	HFBR-25X6 650 nm	200 µm HCS step index NA = 0.37	50 meters with the transceiver in Fig. 7 or Fig. 8
HFBR-14X2 820 nm	HFBR-24X6 820 nm	200 µm HCS step index = 0.37	50 meters with the transceiver in Fig. 7 or Fig. 8
HFBR-14X4 820 nm	HFBR-24X6 820 nm	62.5/125 µm multimode glass	500 meters with the transceiver in Fig. 7 or Fig. 8
HFBR-13X2 1300 nm	HFBR-23X6 1300 nm	62.5/125 µm multimode glass	2 kilometers with the transceiver in Fig. 7 or Fig. 8
HFBR-1315 1300 nm	HFBR-2315 1300 nm	9/125 µm single-mode glass	6 kilometers with the transceiver in Fig. 7 or Fig 8

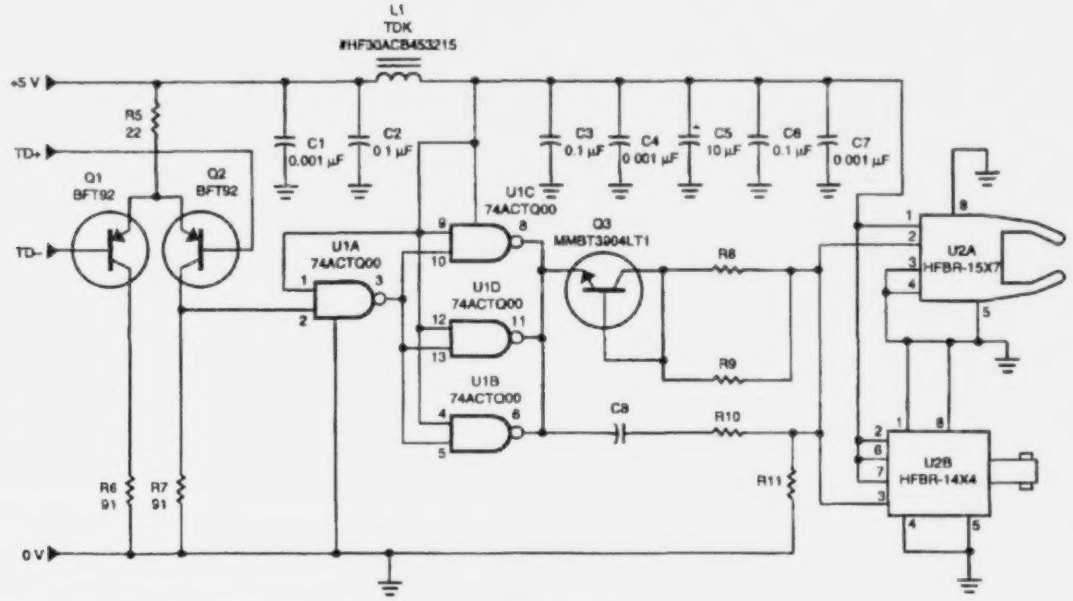

L1
TDK
#HF30ACB453215
+5 V
R5
22
TD+
TD-
Q1
BFT92
Q2
BFT92
C1
0.001 µF
C2
0.1 µF
C3
0.1 µF
C4
0.001 µF
C5
10 µF
C6
0.1 µF
C7
0.001 µF
U1C
74ACTQ00
U1A
74ACTQ00
U1D
74ACTQ00
U1B
74ACTQ00
Q3
MMBT3904LT1
R8
R9
C8
R10
R11
R6
91
R7
91
0 V
U2A
HFBR-15X7
U2B
HFBR-14X4

Figure 3. +5 V ECL (PECL-compatible) 160 MBd Fiber-optic Transmitter

Table 2

Transmitter	**HFBR-15X7 650 nm LED**		**HFBR-14X2 820 nm LED**	**HFBR-14X4 820 nm LED**	**HFBR-13X2 1300 nm LED**	**HFBR-13X5 1300 nm ELED**
Fiber Type	1 mm Plastic	200 µm HCS	200 µm HCS	62.5/125 µm	62.5/125 µm	9/125 µm
R8	301 Ω	82.5 Ω	300 Ω	84.5 Ω	78.7 Ω	53.6 Ω
R9	301 Ω	82.5 Ω	300 Ω	84.5 Ω	78.7 Ω	53.6 Ω
R10	15 Ω	15 Ω	82 Ω	56 Ω	47 Ω	33 Ω
R11	1 kΩ	475 Ω	2.2 kΩ	2.2 kΩ	∞	1.2 kΩ
C8	43 pF	120 pF	18 pF	33 pF	56 pF	56 pF

A Complete Fiber-Optic Transceiver Solution

Figure 6 shows the schematic for a complete fiber-optic transceiver. This transceiver is constructed on a printed circuit, which is 1" wide by 1.97" long, using surface-mount components. When the transceiver shown in Figure 6 is tested at a data rate of 155.5 MBd, using a 50 m length of 1 mm diameter plastic optical fiber with a numerical aperture (N.A.) of 0.33, it provides a typical eye opening of 3.6 ns at a BER of $\leq 1.1\times10^{-10}$. Designers interested in inexpensive solutions are encouraged to embed the complete fiber-optic transceiver described in this application note into the next generation of new data communication products. The circuit in Figure 6 matches the electrical functions of industry-standard 1300 nm transceiver modules, with the exception that there is no signal-detect function in the Figure 6 circuit (pin 4 is nonfunctional). If your system's protocol requires a signal-detect feature, the transceiver shown in Figure 7 will provide it. The transceiver circuits shown in Figure 6 or Figure 7 can be directly inserted into boards designed for industry-standard fiber-optic transceivers modules with a 1X9 footprint and used as a cost-effective alternative in industrial, medical, telecom and proprietary data communication applications.

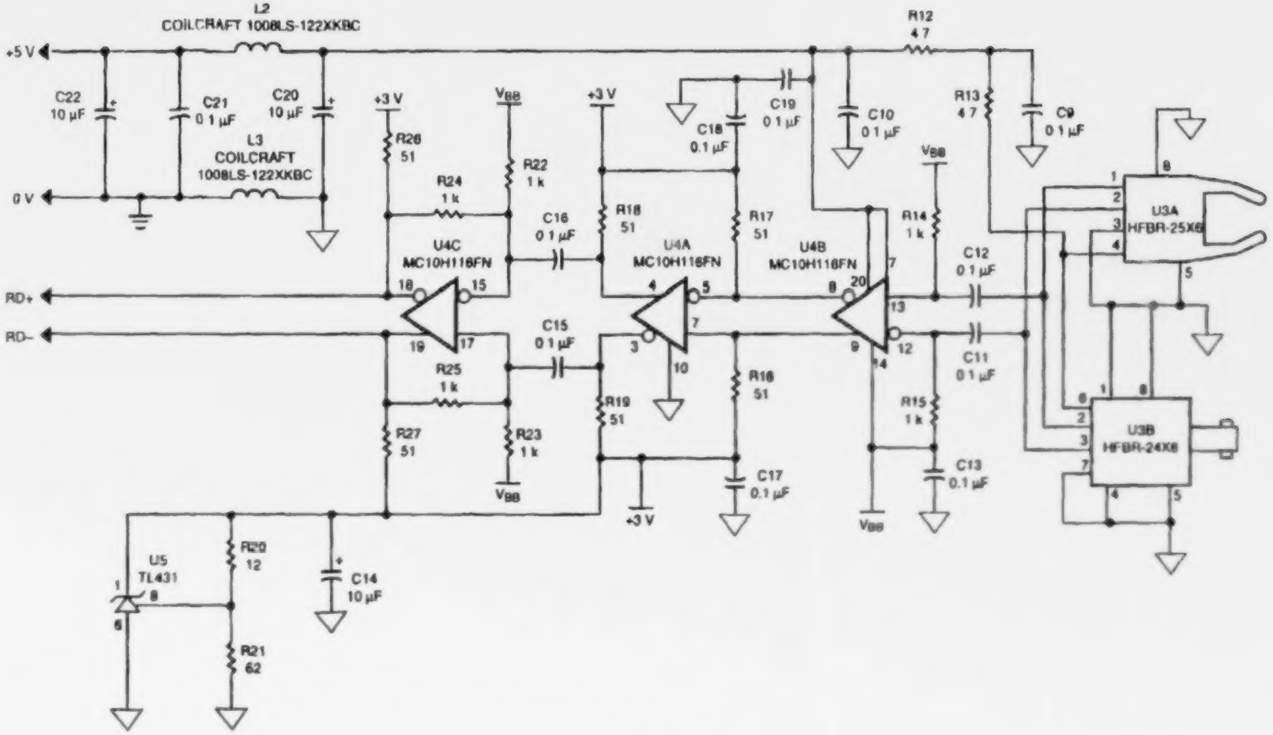

L2
COILCRAFT 1008LS-122XKBC
+5 V
C22
10 µF
C21
0.1 µF
C20
10 µF
L3
COILCRAFT
1008LS-122XKBC
0 V
RD+
RD–
+3 V
R26
51
R24
1 k
R22
1 k
V_BB
U4C
MC10H116FN
18
15
19
17
C16
0.1 µF
C15
0.1 µF
R25
1 k
R27
51
R23
1 k
+3 V
R18
51
R19
51
U4A
MC10H116FN
4
5
3
7
10
C18
0.1 µF
C19
0.1 µF
R17
51
R16
51
C17
0.1 µF
U4B
MC10H116FN
8
20
7
13
9
12
14
C10
0.1 µF
R12
4.7
R13
4.7
C9
0.1 µF
R14
1 k
R15
1 k
C12
0.1 µF
C11
0.1 µF
C13
0.1 µF
U3A
HFBR-25X6
U3B
HFBR-24X6
U5
TL431
R20
12
R21
62
C14
10 µF

Figure 4. +5 V ECL (PECL-compatible) 160 MBd Fiber-optic Receiver

Table 3

Receiver	HFBR-25X6 650 nm		HFBR-24X6 820 nm	HFBR-23X6 1300 nm	HFBR-2315 1300 nm
Fiber Type	1 mm Plastic	200 µm HCS	62.5/125 µm	62.5/125 µm	9/125 µm

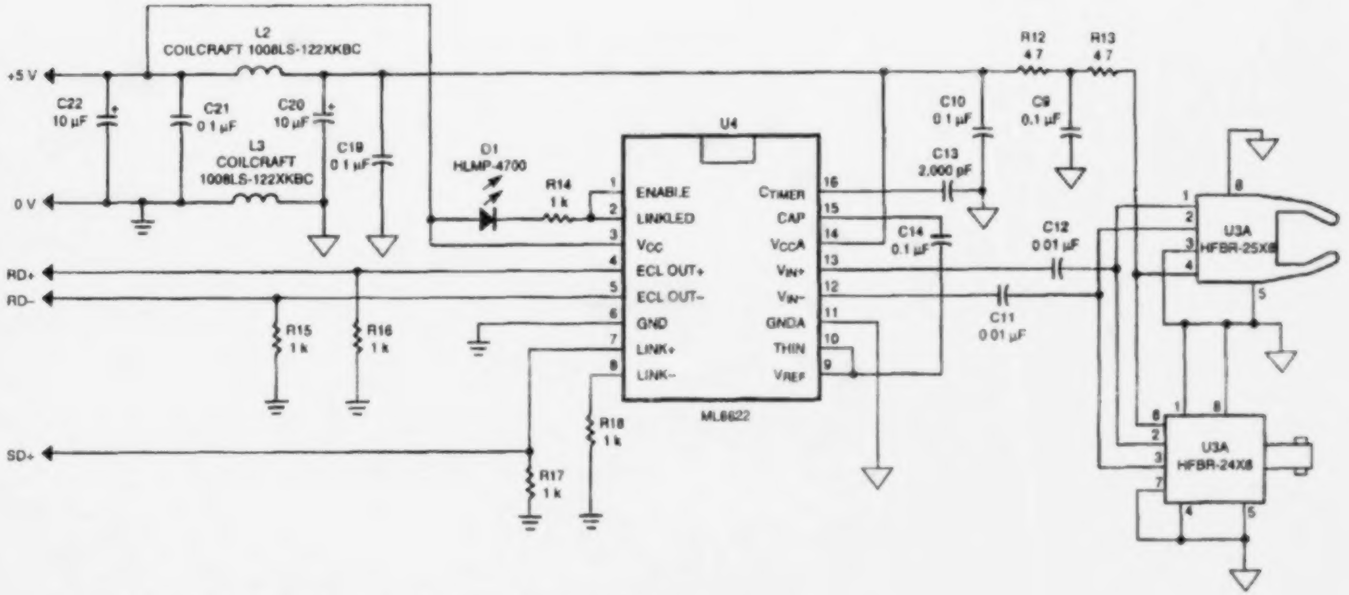

+5 V
0 V
RD+
RD−
SD+
L2
COILCRAFT 1008LS-122XKBC
L3
COILCRAFT 1008LS-122XKBC
C22
10 µF
C21
0.1 µF
C20
10 µF
C19
0.1 µF
D1
HLMP-4700
R14
1 k
R15
1 k
R16
1 k
R17
1 k
R18
1 k
U4
ML6622
ENABLE
LINKLED
VCC
ECL OUT+
ECL OUT−
GND
LINK+
LINK−
CTIMER
CAP
VCCA
VIN+
VIN−
GNDA
THIN
VREF
C10
0.1 µF
C13
2,000 pF
C14
0.1 µF
C9
0.1 µF
R12
4.7
R13
4.7
C12
0.01 µF
C11
0.01 µF
U3A
HFBR-25X8
U3A
HFBR-24X8

Figure 5. PECL-compatible 160 MBd Fiber-optic Receiver with Signal-Detect Function

Table 4

Receiver	HFBR-25X6 650 nm		HFBR-24X6 820 nm	HFBR-23X6 1300 nm	HFBR-2315 1300 nm
Fiber Type	1 mm Plastic	200 µm HCS	62.5/125 µm	62.5/125 µm	9/125 µm

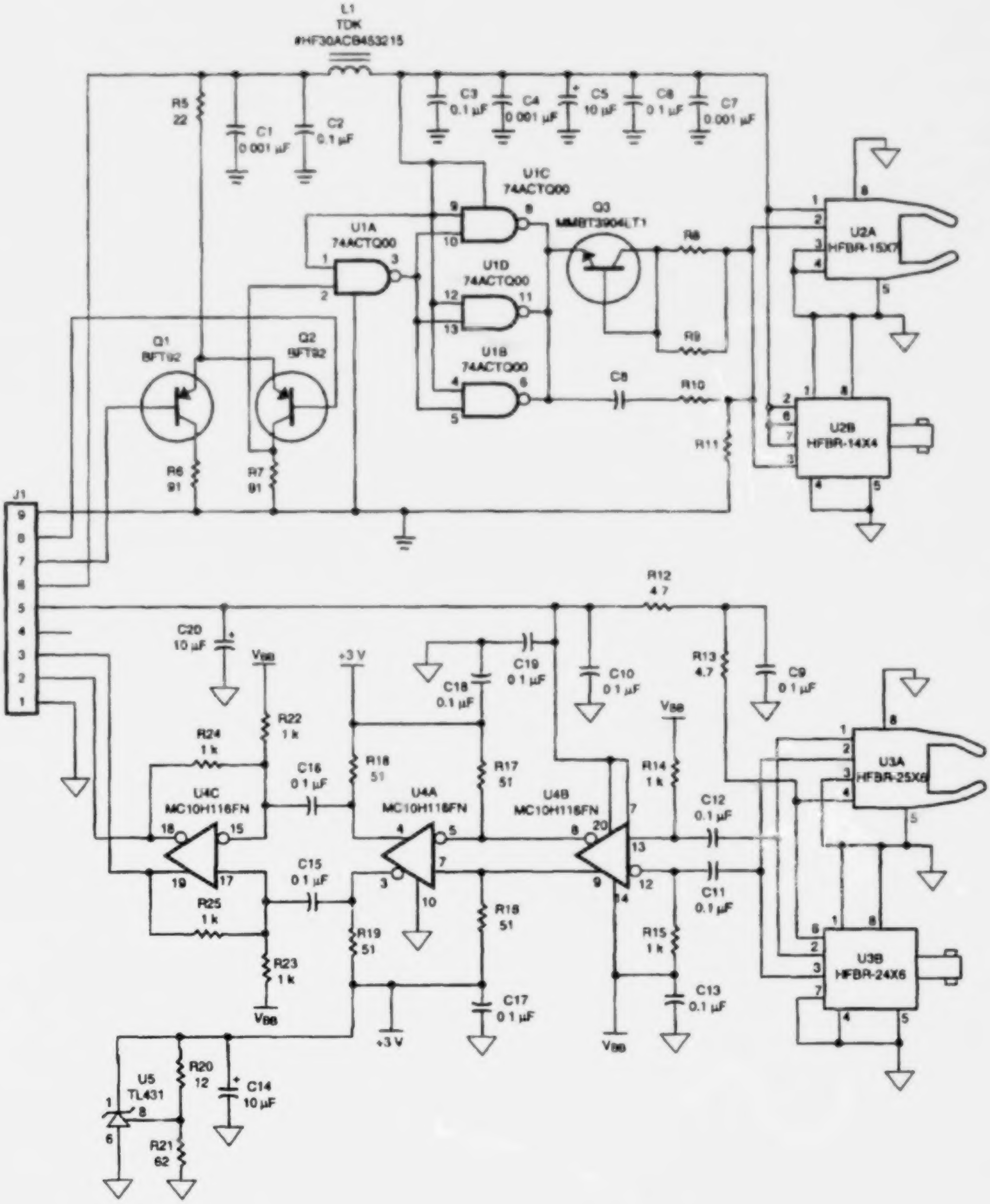

L1
TDK
#HF30ACB453215
R5
22
C1
0.001 µF
C2
0.1 µF
C3
0.1 µF
C4
0.001 µF
C5
10 µF
C6
0.1 µF
C7
0.001 µF
U1C
74ACTQ00
U1A
74ACTQ00
U1D
74ACTQ00
U1B
74ACTQ00
Q3
MMBT3904LT1
R8
R9
C8
R10
R11
Q1
BFT92
Q2
BFT92
R6
91
R7
91
U2A
HFBR-15X7
U2B
HFBR-14X4
J1
R12
4.7
R13
4.7
C20
10 µF
C9
0.1 µF
C10
0.1 µF
C18
0.1 µF
C19
0.1 µF
VBB
+3 V
R22
1 k
R24
1 k
C16
0.1 µF
R18
51
R17
51
R14
1 k
U4C
MC10H116FN
U4A
MC10H116FN
U4B
MC10H116FN
C12
0.1 µF
C11
0.1 µF
C15
0.1 µF
R25
1 k
R16
51
R19
51
R15
1 k
R23
1 k
C13
0.1 µF
C17
0.1 µF
U3A
HFBR-25X6
U3B
HFBR-24X6
U5
TL431
R20
12
C14
10 µF
R21
62

Figure 6. Lowest Cost 160 MBd Fiber-optic Transceiver

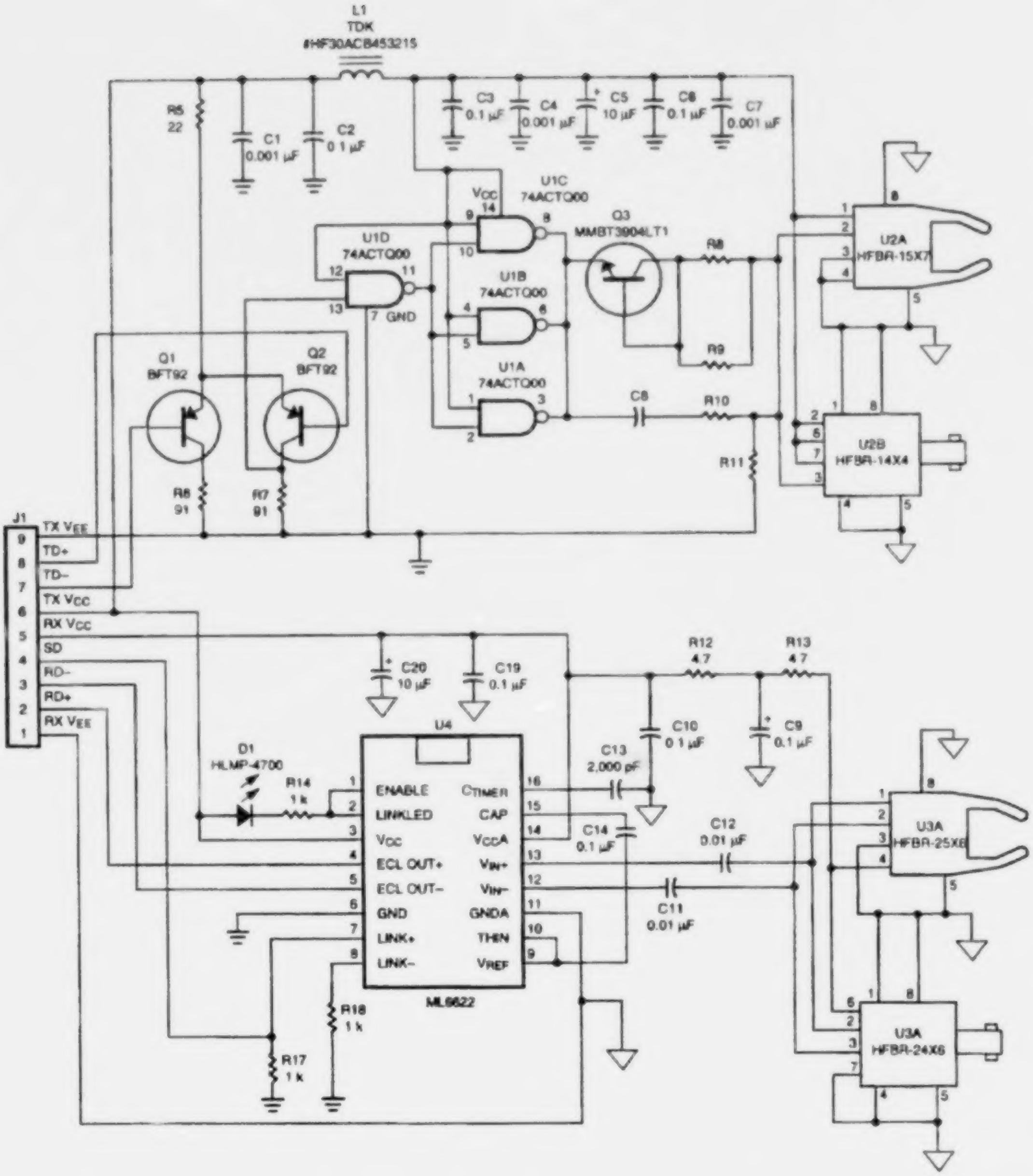

L1
TDK
#HF30ACB453215
R5
22
C1
0.001 µF
C2
0.1 µF
C3
0.1 µF
C4
0.001 µF
C5
10 µF
C6
0.1 µF
C7
0.001 µF
U1C
74ACTQ00
Vcc
14
9
8
10
U1D
74ACTQ00
12
11
13
7 GND
U1B
74ACTQ00
4
6
5
U1A
74ACTQ00
1
3
2
Q3
MMBT3904LT1
R8
R9
C8
R10
R11
Q1
BFT92
Q2
BFT92
R6
91
R7
91
U2A
HFBR-15X7
U2B
HFBR-14X4
J1
TX VEE
TD+
TD−
TX VCC
RX VCC
SD
RD−
RD+
RX VEE
C20
10 µF
C19
0.1 µF
U4
R12
4.7
R13
4.7
C10
0.1 µF
C9
0.1 µF
C13
2,000 pF
D1
HLMP-4700
R14
1 k
ENABLE
LINKLED
VCC
ECL OUT+
ECL OUT−
GND
LINK+
LINK−
CTIMER
CAP
VCCA
VIN+
VIN−
GNDA
THIN
VREF
ML6622
C14
0.1 µF
C12
0.01 µF
C11
0.01 µF
R18
1 k
R17
1 k
U3A
HFBR-25X6
U3A
HFBR-24X6

Figure 7. Full-featured 160 MBd Fiber-optic Transceiver with Signal-Detect Function

Signal Terminations and Power Supply Filtering Requirements

If the proper signal terminations and power supply filter circuits are used, the transceiver circuits in Figure 6 and Figure 7 have been proven to provide excellent performance. When using serializer and deserializer chips that provide PECL-compatible high-speed serial inputs and outputs, the power supply filter and terminations shown in Figure 8 are required. The signal terminations and power supply filtering shown in Figure 9 are required if the fiber-optic transceivers recommended in this application note are used with the PMC-Sierra PM5946 S/UNI-LITE chip for SONET OC-3 applications.

Error Rates and Noise Immunity

The probability that a fiber-optic link will make an error is related to the receiver's own internal random noise and the receiver's ability to reject noise originating from the system in which it is installed. The total noise present in any fiber-optic receiver is normally the sum of the PIN diode pre-amplifier's noise and the host

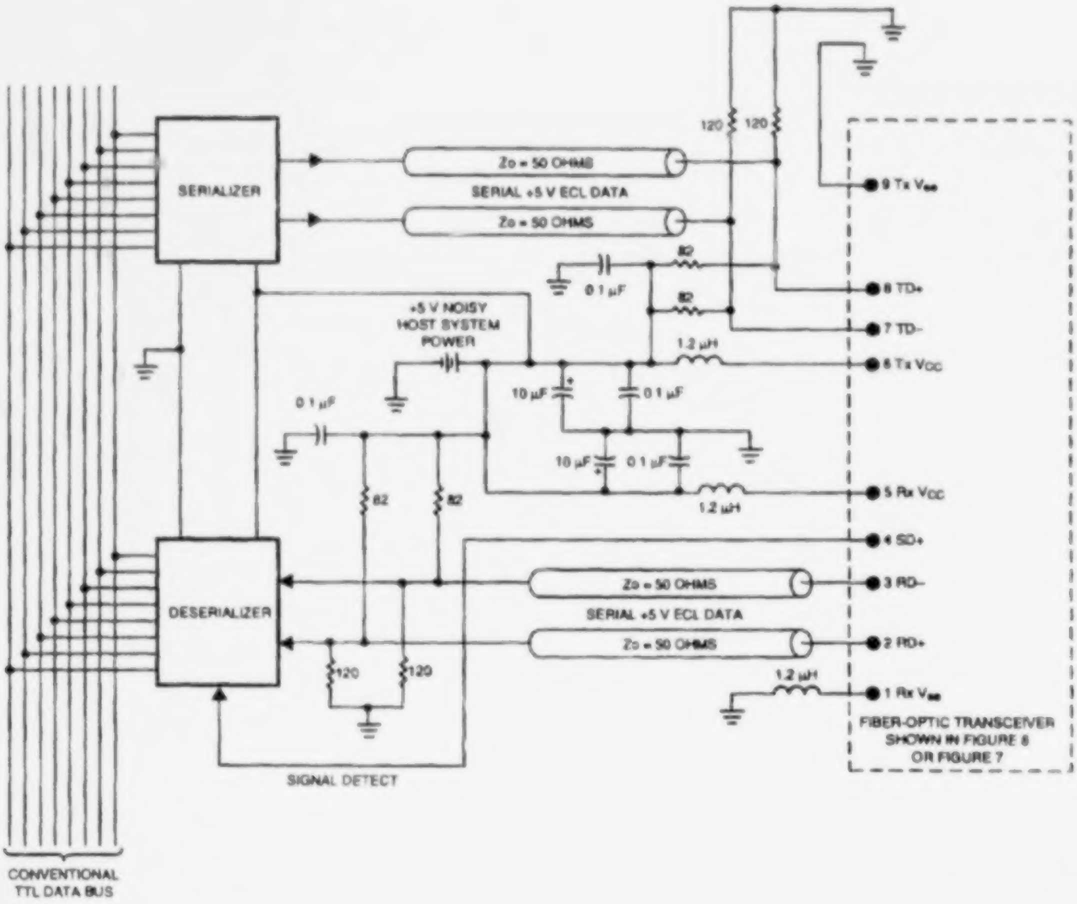

SERIALIZER
DESERIALIZER
Zo = 50 OHMS
SERIAL +5 V ECL DATA
Zo = 50 OHMS
120
120
82
82
0.1 µF
+5 V NOISY HOST SYSTEM POWER
1.2 µH
10 µF
0.1 µF
0.1 µF
10 µF
0.1 µF
1.2 µH
82
82
Zo = 50 OHMS
SERIAL +5 V ECL DATA
Zo = 50 OHMS
120
120
1.2 µH
9 Tx Vee
8 TD+
7 TD−
6 Tx VCC
5 Rx VCC
4 SD+
3 RD−
2 RD+
1 Rx Vee
FIBER-OPTIC TRANSCEIVER SHOWN IN FIGURE 6 OR FIGURE 7
SIGNAL DETECT
CONVENTIONAL TTL DATA BUS

Figure 8 **Recommended Power Supply Filter and +5 V ECL (PECL) Signal Terminations for the AMD TAXIchip™ and Cypress HOTLink™**

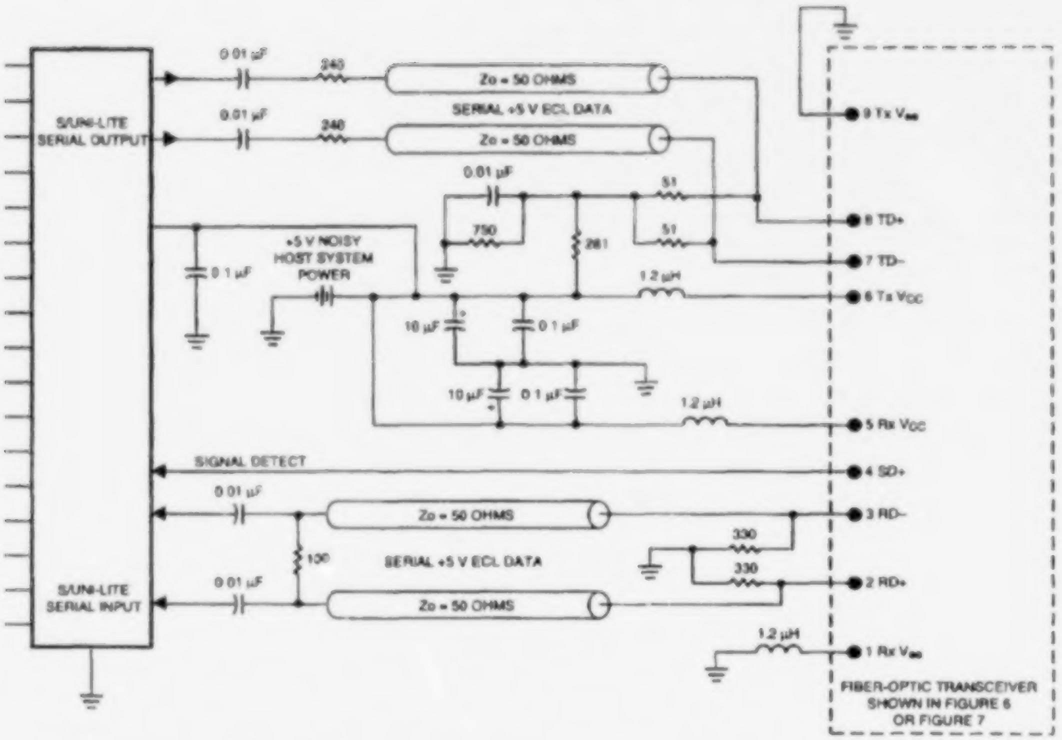

0.01 µF
240
Zo = 50 OHMS
SERIAL +5 V ECL DATA
S/UNI-LITE
SERIAL OUTPUT
0.01 µF
240
Zo = 50 OHMS
0.01 µF
51
750
281
51
0.1 µF
+5 V NOISY
HOST SYSTEM
POWER
1.2 µH
10 µF
0.1 µF
10 µF
0.1 µF
1.2 µH
9 Tx Vee
8 TD+
7 TD-
6 Tx Vcc
5 Rx Vcc
SIGNAL DETECT
4 SD+
0.01 µF
Zo = 50 OHMS
3 RD-
100
SERIAL +5 V ECL DATA
330
330
2 RD+
S/UNI-LITE
SERIAL INPUT
0.01 µF
Zo = 50 OHMS
1.2 µH
1 Rx Vee
FIBER-OPTIC TRANSCEIVER
SHOWN IN FIGURE 6
OR FIGURE 7

Figure 9. Recommended Power Supply Filter and +5 V ECL (PECL) Signal Terminations for the PMC-Sierra PM5946 S/UNI-LITE™

system's electrical noise. As the optical signal applied to the receiver increases, the probability that the receiver's total noise will alter the data decreases. Small increases in the receiver's signal-to-noise ratio will result in a very sharp reduction in the probability of error. Figure 10 shows that the receiver's probability of error is reduced by 6 orders of magnitude (from 1×10^{-9} to 1×10^{-15}) when the receiver's signal-to-noise ratio improves from 12:1 to 15.8:1.

At any fixed temperature, the total value of the receiver's random noise plus the host system's noise can be assumed to be a constant, so the most obvious way to reduce the probability of error is to increase the amplitude of the optical signal applied to the receiver. A less obvious technique for lowering the error rate is to improve the receiver's ability to reject electrical noise from the system in which it resides. The fiber-optic receivers recommended in this application note have sufficient noise immunity to be used in most systems without electrostatic shielding. The Agilent PIN diode pre-amps, which are used in the receiver's first stage, are physically small hybrid circuits, and they do not function as particularly effective antennas. For

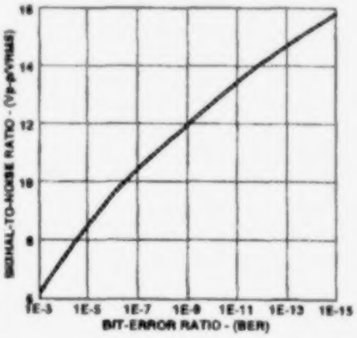


Figure 10. Receiver Signal-to-Noise Ratio vs. Probability of Error (aka BER)

extremely noisy applications, Agilent offers PIN diode pre-amps in electrically conductive plastic or metal packages. Agilent manufactures a wide range conductive and non-conductive fiber-optic components that mate with various industry standard fiber-optic connectors, but the overwhelming majority of the fiber-optic applications successfully implemented with Agilent's fiber-optic components have not required conductive plastic or metal receiver housings.

The most insidious and the most overlooked source of noise is usually the host system's +5V power supply. The host system's +5 volt supply normally powers the fiber-optic receiver, the fiber-optic transmitter and an entire system comprised of relatively noisy digital circuits. The simple and inexpensive power supply filters shown in Figure 8 and Figure 9 of this publication have been proven to work in a wide range of system applications and these recommended power supply filters are normally sufficient to protect the fiber-optic receiver from very noisy host systems.

Printed Circuit Artwork

The performance of transceivers that use Agilent fiber-optic components are partially dependent on the layout of the printed circuit board on which the transceiver circuits are constructed. To achieve the fiber-optic link performance described in Table 1 system designers are encouraged to imbed the printed circuit design provided in this application note. The printed circuit artwork in Figure 11 is for the transceiver shown in Figure 6. If your system requires a fiber-optic receiver with a signal-detect feature, the artwork shown in Figure 12 can be used to construct the transceiver shown in Figure 7. Electronic copies of the "Gerber" files for the artwork shown in this application note can be obtained by using the Internet to download the printed circuit designs located at the following URL:

http://www.agilent.com/Agilent-COMP/fiber/fiber_index.html

Download the file named **raftv3.exe** to obtain the artwork for the transceiver shown in Figure 6. Download the file named **sor_v3.exe** to obtain the artwork for the transceiver shown in Figure 7.

Parts List

The PECL-compatible fiber-optic transceivers recommended in this publication are very simple and inexpensive, so only a few external components are needed. Complete parts lists are provided in Table 5 and Table 6. All of the components are compatible with the printed circuit artworks shown in Figures 11 and 12, thus minimizing the design time and resources needed to use the low cost fiber-optic transceivers shown in this application note.

Conclusion

The complete PECL-compatible fiber-optic transceiver solutions provided in this publication can be used to build new data communication systems that work at higher data rates and provide better noise immunity than possible with copper wire. When fiber-optic media is used in place of conventional copper wire, it is possible to build new communication systems that are immune to large noise transients caused by utility power switch gear, motor drives or high-voltage power supplies. Furthermore, the non-conductive cables used in optical communication links have an intrinsically higher probability of surviving lightning strikes than copper wire alternatives. The optical data communication solutions shown in this application note can also send high-speed, 160 MBd data over long distances impossible with copper wire cables. By imbedding the complete solutions shown in this application note, system designers can quickly develop a new generation of high-speed, noise-immune, optical communication links in a very short time with minimal research and development costs.

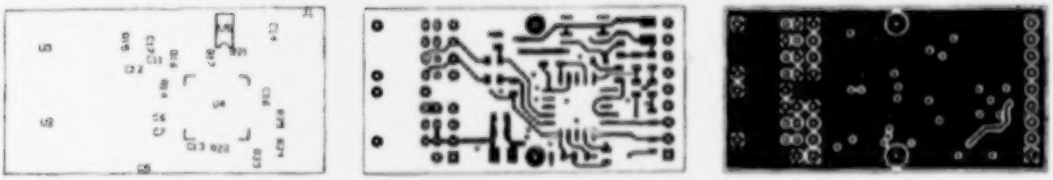


Figure 11a. Top Overlay

Figure 11b. Top Layer

Figure 11c. Mid Layer 2

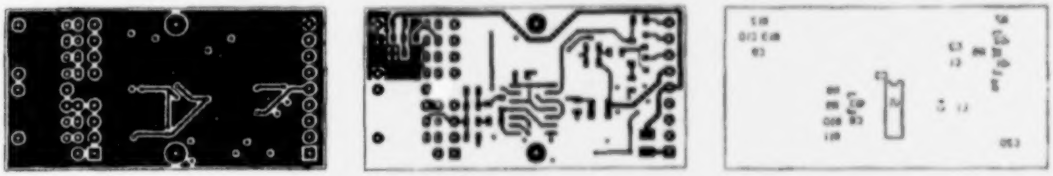


Figure 11d. Mid Layer 3

Figure 11e. Bottom Layer

Figure 11f. Bottom Overlay

WARNING: DO NOT USE PHOTO-COPIES OR FAX COPIES OF THIS ARTWORK TO FABRICATE PRINTED CIRCUITS.

Figure 11. Printed Circuit Artwork for Transceiver shown in Figure 6

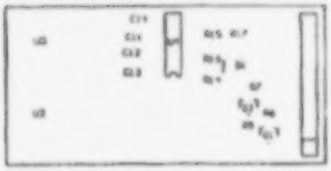


Figure 12a. Top Overlay

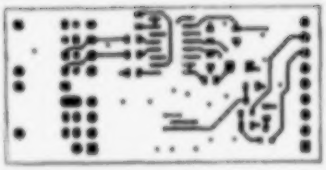


Figure 12b. Top Layer

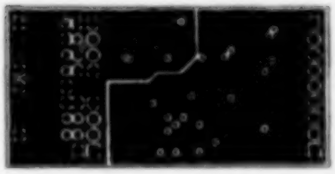


Figure 12c. Mid Layer 2

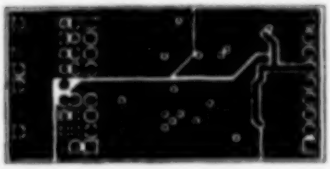


Figure 12d. Mid Layer 3

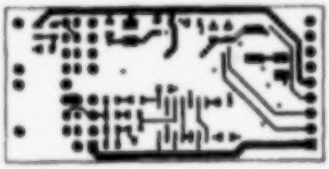


Figure 12e. Bottom Layer

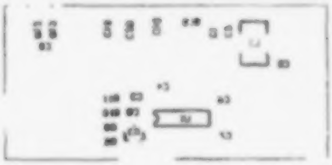


Figure 12f. Bottom Overlay

WARNING: DO NOT USE PHOTOCOPIES OR FAX COPIES OF THIS ARTWORK TO FABRICATE PRINTED CIRCUITS.

Figure 12. Printed Circuit Artwork for Transceiver shown in Figure 7

Table 5. Parts List for the Transceiver in Figure 6

Designator	Part Type	Description	Footprint	Material	Part Number	Quantity	Vendor 1
C1	0.001 µF	Capacitor	805	NPO/COG	C0805NPO500102JNE	3	Venkel
C4	0.001 µF	Capacitor					
C7	0.001 µF	Capacitor					
C10	0.1 µF	Capacitor	805	X7R or better	C0805X7R500104KNE	13	Venkel
C11	0.1 µF	Capacitor					
C12	0.1 µF	Capacitor					
C13	0.1 µF	Capacitor					
C15	0.1 µF	Capacitor					
C16	0.1 µF	Capacitor					
C17	0.1 µF	Capacitor					
C18	0.1 µF	Capacitor					
C19	0.1 µF	Capacitor					
C2	0.1 µF	Capacitor					
C3	0.1 µF	Capacitor					
C6	0.1 µF	Capacitor					
C9	0.1 µF	Capacitor					
C14	10 µF	Capacitor	B	Tantalum, 10 V	TA010TCM106MBN	3	Venkel
C20	10 µF	Capacitor					
C5	10 uF	Capacitor					
C8	See Table 2	Capacitor	805	NPO/COG		1	Venkel
U1	I.C	Nand Gate	SO14		74ACTQ00	1	National
U2	Fiber-Optic	Transmitter		See Table 2	HFBR-1XXX	1	Agilent
U3	Fiber-Optic	Receiver		See Table 2	HFBR-2XXX	1	Agilent
U4	MC10H116FN	IC,ECL line rec.	PLCC20		MC10H116FN	1	Motorola
U5	TL431CD	IC, Voltage Reg.	SO-8		TL431CD	1	T.I.
L1	CB70-1812	Inductor	1812		HF30ACB453215	1	TDK
R12	4.7	Resistor	805	5%	CR080510W4R7JT	2	Venkel
R13	4.7	Resistor					
R20	12	Resistor	805	5%	CR080510W120JT	1	Venkel
R10	See Table 2	Resistor	805	5%		1	Venkel
R5	22	Resistor	805	5%	CR080510W220JT	1	Venkel
R16	51	Resistor	805	5%	CR080510W510JT	4	Venkel
R17	81	Resistor					
R18	51	Resistor					
R19	51	Resistor					
R21	62	Resistor	805	5%	CR080510W620JT	1	Venkel
R8	See Table 2	Resistor	805	1%		2	Venkel
R9	See Table 2	Resistor					
R6	91	Resistor	805	5%	CR080510W910JT	2	Venkel
R7	91	Resistor					
R11	See Table 2	Resistor	805	1%		1	Venkel
R14	1 k	Resistor	805	5%	CR080510W102JT	6	Venkel
R15	1 k	Resistor					
R22	1 k	Resistor					
R23	1 k	Resistor					
R24	1 k	Resistor					
R25	1 k	Resistor					
Q1	BFT92	Transistor	SOT-23		BFT92	2	Philips
Q2	BFT92	Transistor					
Q3	MMBT3904LT1	Transistor	SOT-23		MMBT3904LT1	1	Motorola
J1		Pins			343B	9	McKenzie

Table 6. Parts List for the Transceiver in Figure 7

Designator	Part Type	Description	Footprint	Material	Part Number	Quantity	Vendor 1
C1 C4 C7	0.001 µF 0.001 µF 0.001 µF	Capacitor	805	NPO/COG	C0805NPO500102JNE	3	Venkel
C2 C3 C6 C9 C10 C14 C19	0.1 µF 0.1 µF 0.1 µF 0.1 µF 0.1 µF 0.1 µF 0.1 µF	Capacitor Capacitor Capacitor Capacitor Capacitor Capacitor Capacitor	805	X7R or better	C0805X7R500104KNE	7	Venkel
C5 C20	10 µF 10 µF	Capacitor Capacitor	B	Tantalum, 10 V	TA010TCM106MBN	2	Venkel
C8	See Table 2	Capacitor	805	NPO/COG		1	Venkel
C11 C12	0.01 µF 0.01 µF	Capacitor Capacitor	805	X7R or better	C0805X7R500103JNE	2	Venkel
C13	2,000 pF	Capacitor	805	NPO/COG	C0805NP0500202JNE	1	Venkel
D1	HLMP-4700	LED lamp			HLMP-4700	1	Agilent
U1	I.C.	Nand Gate	SO14		74ACTQ00	1	National
U2	Fiber-Optic	Transmitter		See Table 2	HFBR-1XXX	1	Agilent
U3	Fiber-Optic	Receiver		See Table 2	HFBR-2XXX	1	Agilent
U4	ML6622	IC, quantizer	SO16		ML6622CS	1	MicroLinear
L1	CB70-1812	Inductor	1812		HF30ACB453215	1	TDK
R12 R13	4.7 4.7	Resistor Resistor	805	5%	CR080510W4R7JT	2	Venkel
R10	See Table 2	Resistor	805	5%		1	Venkel
R5	22	Resistor	805	5%	CR080510W220JT	1	Venkel
R8 R9	See Table 2 See Table 2	Resistor Resistor	805	1%		2	Venkel
R6 R7	91 91	Resistor Resistor	805	5%	CR080510W910JT	2	Venkel
R11	See Table 2	Resistor	805	1%		1	Venkel
R14 R17 R18	1 k 1 k 1 k	Resistor Resistor Resistor	805	5%	CR080510W102JT	3	Venkel
Q1 Q2	BFT92 BFT92	Transistor Transistor	SOT-23		BFT92	2	Philips
Q3	MMBT3904LT1	Transistor	SOT-23		MMBT3904LT1	1	Motorola
J1		Pins			343B	9	McKenzie

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microelectronics group

Lucent Technologies
Bell Labs Innovations

Qualification and Reliability Report

for

1241-Type and 1243-Type 1300nm Laser Transmitters

and

1340-Type and 1345-Type Receivers

June 9, 1998
(Revised September 23, 1998)

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1. INTRODUCTION

Lucent Technologies has extensive experience in assuring the high reliability of optoelectronic components for demanding applications. All Lucent Technologies Optoelectronic devices are subjected to standard qualification programs prior to introduction to manufacture. Product Qualification Tests are executed on production devices under the formal auspices of a Qualification Review Board, made up of representatives of Design, Manufacturing, Quality Control, and Quality Assurance. Lucent Technologies Optoelectronics has an ongoing reliability evaluation program for our optoelectronics product line which includes specific cells designed to assess the aging mechanisms of assembled transmitter and receiver modules. Our qualification program for optoelectronic devices is designed to meet the intent of Bellcore TR-NWT-000468[1] requirements for interoffice applications and TA-NWT-000983[2] requirements for loop applications.

In section two of this report the overall qualification strategy for Lucent Technologies Optoelectronics products is described. Section three presents the qualification plans and results for the 1241-Type and 1243-Type 1300nm transmitter modules and the 1340-Type and 1345-Type receiver modules.

2. LUCENT TECHNOLOGIES OPTOELECTRONICS GROUP QUALIFICATION STRATEGY

Lucent Technologies spends substantial time and effort on ensuring that the design and manufacturing processes are producing devices that exceed the customer requirements with respect to Durability (ability to survive environmental and handling assaults) and Longevity (ability to perform a required function in a tranquil setting for a stated period of time). To be reliable, a device must be both robust (durable) and intrinsically long-lived. Through the combination of careful design, process controls, and extensive testing and burn-in we are able to achieve a highly reliable state of the art product. This broad based commitment to quality is reflected in the design phase, as well as the manufacturing phase of the product life cycle. Early design models and their sub-assemblies are subjected to extensive pre-qualification and reliability testing prior to transfer to manufacturing, to ensure that the design is fundamentally reliable. Our results from the product qualification program, executed on samples from manufacturing will demonstrate our success in meeting our demanding reliability objectives and the results of a long term commitment to quality.

The Lucent Technologies qualification programs for optoelectronic products are controlled by a Qualification Review Board (QRB). The QRB provides a multi-functional body (Design, Quality Assurance, Manufacturing, etc.) to approve qualification plans, review qualification results, and recommend appropriate action for redesign and process changes with regard to qualification. All the qualification programs described here are planned and executed under the auspices of the QRB.

An overall qualification strategy has been developed to assure that the devices supplied to customers will survive the most demanding use environments required of this technology.

In formulating the plan, attention was given both to gain insight about failure modes that might be present, and to control qualification costs.

During development the devices passed through two preliminary stages of qualification, which are considered prequalification:

1. Design Capability Tests (DCT) - Performed early in the development cycle on first laboratory models to determine the capability of the design and aid in the development process by highlighting weaknesses in the design. These tests are harsh mechanical and environmental tests which induce failures of "marginal" devices that, if left uncorrected, might otherwise have failed early on in field use, and guide the designer toward improving reliability.

2. Design Maturity Tests (DMT) - A series of tests applied to final development models believed to be representative of the product manufactured to the final specifications. The DMT are designed to characterize the design fully, to demonstrate that the product meets the design requirements, and to identify long term failure modes. These tests provide assurance to the development team that the product will pass the formal Product Qualification Testing once transferred to production.

   With the completion of the DMT testing the product is transferred to manufacture with a high degree of confidence that all failure modes have been identified and corrective action taken to eliminate them, or to assess their reliability impact so as to insure that the customer requirements are met. Following the start of volume manufacture the formal Product Qualification Testing and Surveillance test programs begin.

3. Product Qualification Tests (PQT) - A formal series of environmental, mechanical, thermal and performance tests are applied to early manufactured product. They provide assurance that the product produced by the manufacturing line can be expected to meet the published specification as manufactured, and after a series of stresses. These tests demonstrate conformance to relevant qualification requirements such as Bellcore TR-NWT-000468[1] and TA-TSY-000983[2].

4. Requalification - A series of tests applied to a device which has undergone modification either by design changes, or from changes in the processing of the device, that might compromise the quality of the device. The specific tests required for requalification are determined by the QRB and will depend on the nature and extent of the process or design changes.

5. Surveillance - An ongoing program that monitors product and process quality and assures the continued product quality established in the PQT phase.

The five types of reliability qualification tests described above (2 preliminary, 3 after manufacture has commenced) form a structure which guarantees product quality by evaluation throughout the development and production life cycle of the device.

The Lucent Technologies Optoelectronics Group was registered to the ISO 9001 Quality Standard in December 1993. This means that all of our processes, from design through manufacture to shipping, adhere to internationally recognized rigorous quality standards.

3. PRODUCT DESCRIPTION, QUALIFICATION AND SURVEILLANCE

3.1 TRANSMITTER

The Lucent Technologies 1241-Type and 1243-Type laser transmitter modules are designed for use in transmission systems and high-speed data communication applications. Used in intraoffice, intermediate-reach and long-reach applications, the transmitters are configured to operate at SONET rates up to OC-12, as well as at ITU-T Synchronous Digital Hierarchy (SDH) rates up to STM-4

The transmitters are designed to meet the performance specifications defined in Bellcore GR-253-CORE requirements, ANSI T1.117-1991 SONET single-mode, and the ITU-T G.957 and G.958 recommendations.

The transmitter module requires a single power supply (+5 V or 5 V) and operates over data rates of 1 Mb/s to 622 Mb/s (NRZ). Automatic power control circuitry provides constant optical output power over the operating temperature range. The automatic power control circuitry also compensates for laser aging.

These transmitters operate over various temperature ranges appropriate for specific applications. The maximum operating case temperature range is 40C to +85C. Manufactured in a 20-pin plastic Dual Inline Package (DIP), the transmitter consists of a hermetic InGaAsP pigtailed laser package, a CMOS laser driver IC, and other discrete components assembled onto a PWB. The low power consumption circuit provides modulation, automatic optical output power control, and data reference. The module can be driven by either ac- or dc-coupled data in single-ended or differential configuration. The only difference between the 1241-Type and 1243-Type is the laser source. The 1241-Type transmitter uses a 1300nm Fabry-Perot laser source and the 1243-Type transmitter uses a 1300nm Distributed Feedback (DFB) laser source.

The launched optical signal is coupled from the laser chip to a 8 µm core singlemode fiber pigtail. The outer jacket diameter of the pigtail is 900 µm.

3.2 RECEIVER

The 1340-Type and 1345-Type receiver modules are designed for use in transmission systems or medium- to high-speed data communications applications at data rates up to 622 Mbits/s.

Two versions of the receiver modules are available: SONET/SDH compliant for the OC-3/STM-1 data rate of 155 Mbits/s, and SONET/SDH compliant for the OC-12/STM-4 data rate of 622 Mbits/s.

The SONET/SDH versions of the receiver meet the performance requirements listed in the latest issue of Bellcore GR-253-CORE and the most recent issues of ITU recommendations G.957 and G.958. The 1340-Type and 1345-Type receiver modules require only a single +5 volt power supply for operation. The receivers operate over various temperature ranges appropriate for specific applications. The maximum operating case temperature range is 40C to +85C. Manufactured in a 20-pin plastic DIP, the receivers use a planar, rear illuminated InGaAsP PIN photodetector that allows these receivers to be used at wavelengths from 1.1 μm to 1.6 μm. The photocurrent output of the PIN detector is amplified and converted to a voltage by a silicon amplifier. A silicon quantizer provides additional signal amplification, data threshold detection, and PECL data outputs. The 1345-Type version adds a timing recovery unit to the 1340-Type receiver circuitry to recover the clock. These ICs along with other discrete components and the detector package are assembled onto a PWB. The receiver has differential PECL data and clock outputs and, depending on version selected, either differential PECL link status flag or complementary CMOS link status flag outputs. The link status flag outputs indicate the presence or absence of a minimum acceptable level of optical input signal.

The incoming optical signal is coupled into the receiver through a 62.5 μm core multimode fiber pigtail. The outer jacket diameter of the pigtail is 900 μm.

3.3 QUALIFICATION

The qualification program for the transmitter and receiver modules is shown in Table 1. The goal of the qualification program for the transmitter and receiver modules was to ensure that they meet the intent of Bellcore TA-TSY-000983[2].

Mechanical Testing Strategy for Module 2000 products

Mechanical testing is aimed at the product's robustness under transportation and handling and to address possible reliability issues under use conditions which may expose the product to mechanical (usually vibration) and temperature excursions (temperature cycling).

Module 2000 product, both transmitters and receivers, are designed using the same mechanical "platform". That is, both use identical PWB technology, interconnect, optical component attachment, snap-in design, and package back-fill processes and design rules. You can draw an analogy of this technology platform to the PWB world. Not every PWB is independently qualified, but a representative PWB design is qualified and those design rules are used for other designs. The components placed on PWBs are qualified as a component so the final, populated PWB is qualified by adhering to the PWB technology platform.

In the Module 2000 case, the components are independently qualified both for mechanical and reliability concerns. We have then selected, we believe, the most sensitive product, the transmitter, and have used that product to qualify the receiver/transmitter Module 2000 mechanical platform. As we have described, the transmitters met all the prescribed Bellcore requirements. This, in our view, validates the platform from the mechanical perspective. Other issues, long term performance aging, resistance to damp heat, and ESD are product specific and are addressed independently as receivers and transmitters.

We believe this strategy, like the analogous PWB strategy, meets the intent of Bellcore and should assure Customers of the robustness of the Module 2000 product."

- Al Walcheski - Lucent Technologies, Optoelectronics Quality Development

TABLE 1

ASSESSMENT OF 1241-Type, 1243-Type TRANSMITTERS AND 1340-Type, 1345-Type RECEIVERS TO BELLCORE TA-NWT-000983 QUALIFICATION REQUIREMENTS

Test	Conditions	Sample Size	Compliance
Mechanical Shock	1500G	11 Transmitters	Passed
Vibration	20G	11 Transmitters	Passed
Thermal Shock	ΔT = 100°C	11 Laser and 11 Detector Packages	Passed
Solderability		5 Transmitters	Passed
Fiber Pull	1kg, 3x, 5sec	11 Laser and 11 Detector Packages	Passed
Accelerating Aging (HTOB)		25 Transmitters 25 Receivers	Passed
High Temperature Storage	85°C	11 Laser and 11 Detector Packages	Passed
Temperature Cycle	-40°C to 85°C; 500 cycles	11 Transmitters	Passed
Damp Heat	40°C/95% RH	11 Transmitters 11 Receivers	Passed
Cyclic Moisture	10 cycles	11 Laser and 11 Detector Packages	Passed
Internal Moisture	<5000 ppm water vapor	11 Laser and 11 Detector Packages	Passed
Flammability		Assessed at part/material level	Passed
ESD Threshold	HBM	6 Transmitters 6 Receivers	Passed
Lead Integrity		5 Transmitters	Passed
Solvent Resistance		5 Transmitters	Passed

3.3.1 MECHANICAL INTEGRITY TESTS

3.3.1.2 Sine Swept Vibration

Eleven transmitters were subjected to sinusoidal vibration testing. Each transmitter was exposed to four, four minute cycles of variable frequency vibrations from 20Hz to 2000Hz with 20G of acceleration. The stress was applied along each of the principal axis and was performed in accordance with MIL-STD-883E, Method 2007.1. Each transmitter was subjected to a full electrical/optical parametric test after vibration testing was complete.

3.3.1.1 Mechanical Shock

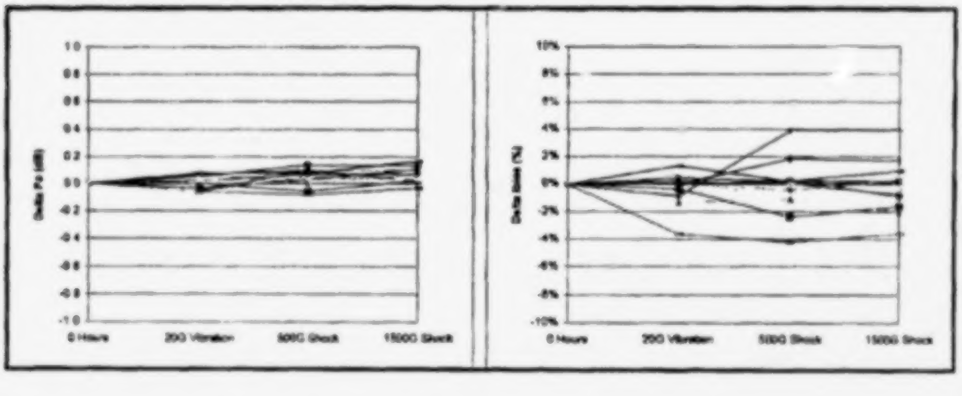
The same eleven transmitters used in the Vibration test were then exposed to mechanical shock by subjecting them to shocks of 500G (Bellcore requirement) and 1500G. Each device received five blows along each of the principle axis (+X, -X, +Y, -Y, +Z and -Z) at each level of testing. The tests were performed in accordance with MIL-STD-883E, Method 2002, Condition B. Each transmitter was subjected to a full electrical/optical parametric test after each level of shock.

Shock / Vibration Test Results

After each phase of vibration and shock testing, the eleven transmitters were subjected to the complete set of manufacturing test requirements. The plots shown below are for the two key parameters (Delta Optical Power Output - Po and Delta Bias Current - Ibias) identified to monitor changes in device operation. The limits used for this qualification were less than or equal to 1 dB change in optical power output and less than or equal to a 10% change in bias current for transmitter modules; and, less than or equal to a 1 dB change in Bit-Error-Rate (BER) sensitivity for receiver modules.

All eleven transmitters met these requirements.

Results of Transmitter Vibration and Shock Testing



3.3.1.3 Solderability

The solderability test was performed on 5 transmitters per MIL-STD-883E.
Failure criteria - All leads shall have >95% coverage of solder and any pinholes, voids, porosity, nonwetting or dewetting are not to be concentrated in any one area and shall not exceed 5% of the total area.

All leads passed this test.

3.3.1.4 Fiber Pull

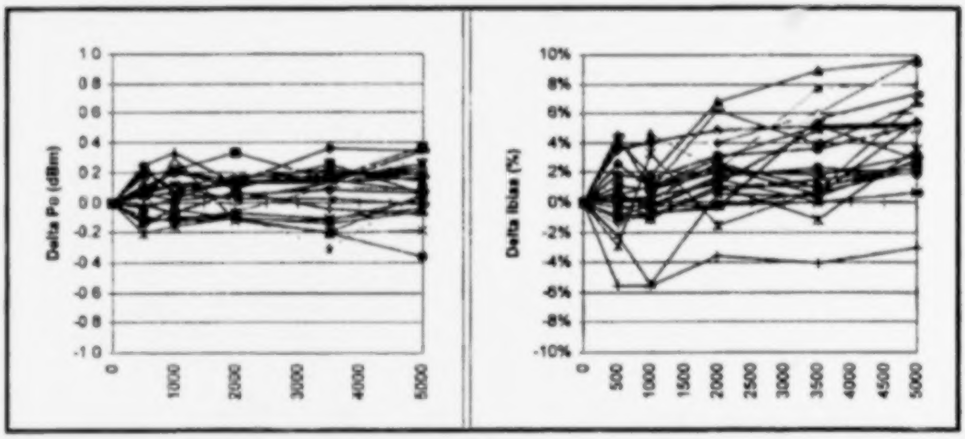
The fiber pull test was performed on eleven D171 PIN detector modules and eleven D370 laser modules used in the construction of 1340-Type and 1345-Type receivers, and 1241-Type and 1243-Type transmitter modules. Since the detector and laser modules form part of the receiver and transmitter modules after assembly, qualification tests can be performed on the individual components. The test consists of axially loading the fiber with 1kg and 2 kg weights for a measured period of time, releasing the weight, then measuring photocurrent. All devices passed this test.

3.3.2 ENDURANCE TESTS

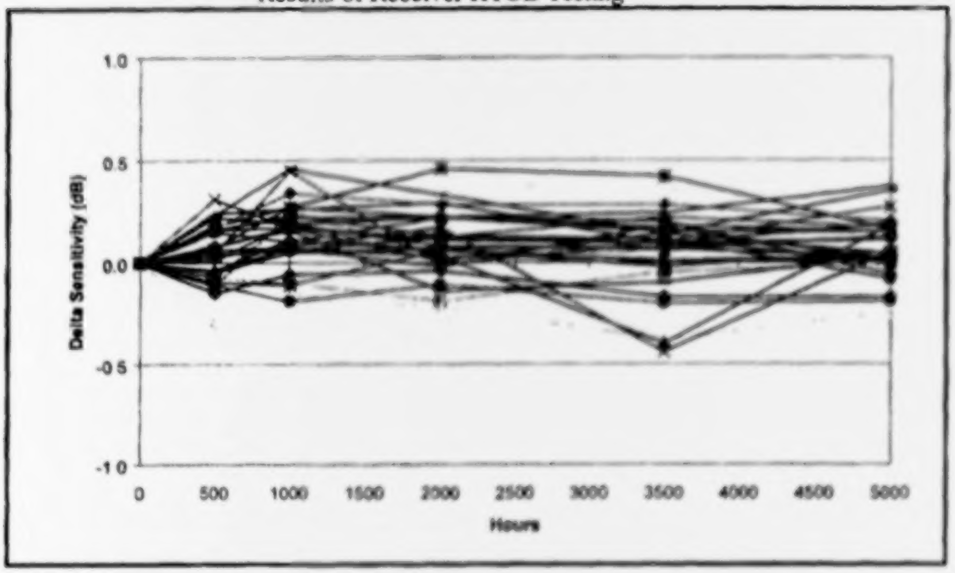
3.3.2.1 High Temperature Aging (HTOB)

Twenty-five transmitters and twenty-five receivers were aged at 85C under bias for the required 5000 hours. No failures occurred after 5000 hours of HTOB.

Results of Transmitter HTOB Testing

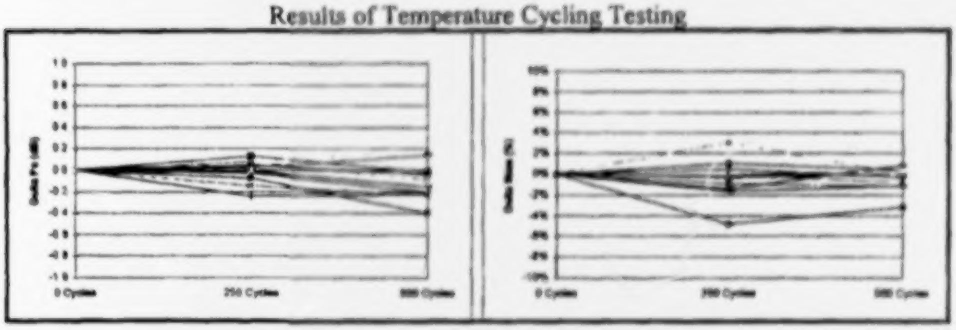


Results of Receiver HTOB Testing



3.3.2.3 **Temperature Cycling** - Eleven transmitters were temperature cycled per Bellcore TA-NWT-000983, Section 5.2, 500 times from -40C to +85C. No devices failed the requirements.

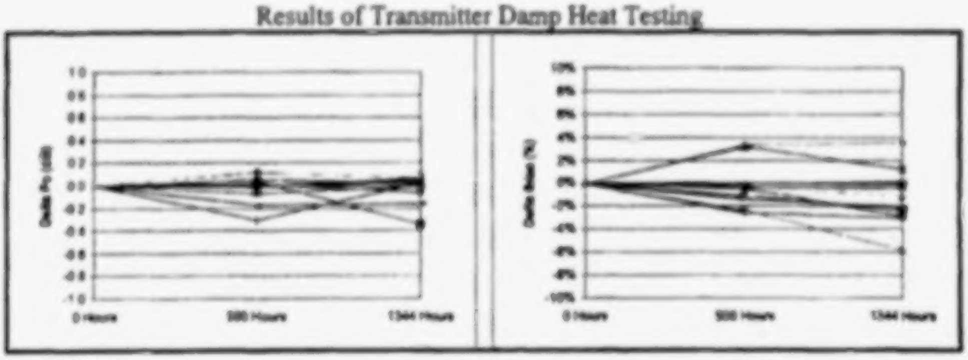
Results of Temperature Cycling Testing



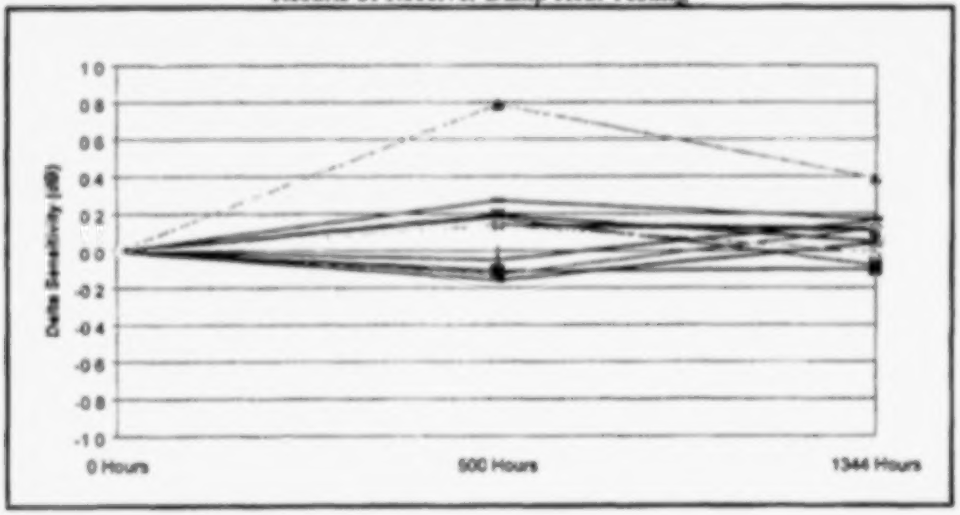
3.3.2.4 Damp Heat (40C/95% Relative Humidity)

Eleven transmitters and eleven receivers were subjected to 1344 hours of damp heat per MIL-STD-202, Method 103. No devices failed the requirements after being subjected to this test.

Results of Transmitter Damp Heat Testing



Results of Receiver Damp Heat Testing



3.3.3 SPECIAL TESTS

3.3.3.2 ESD Threshold

Bellcore requires that the receiver module be tested for ESD withstand threshold voltage using the Human Body Model (HBM). For ESD testing, Lucent references internal Lucent Bell Laboratories specification X-19435, "Test Methods and Requirements for Electrostatic Discharge Withstand Thresholds of Microelectronic Devices"

The transmitter and receiver was tested for ESD withstand threshold voltage using the Human Body Model (HBM). In this test, a 100 pF, 5 KV capacitor is charged up to the test voltage, then discharged into the pin(s) to be tested through a 1500Ω ± 5%, low shunt capacitance (<1 pF) resistor. The test requires that at each test voltage level, five (5) pulses of each polarity, with a 1-second interval between pulses, be applied to each pin to be tested. The pin combinations to be tested are:

a. Stress each input (or output) pin while grounding all power supply pins.

b. Stress each power supply pin while grounding each differently named power supply pin.

c. Stress each input (or output) pin while grounding all output (or input) pins.

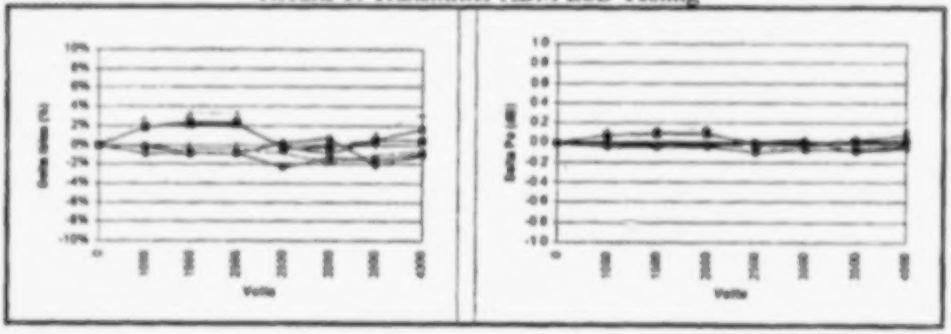
The *Lucent Electrostatic Discharge (ESD) Control Handbook* divides the degree of ESD protection into four classes, Class 0 through Class III. Table 2 shows the withstand voltage for the four classes and also compares these levels to the withstand threshold voltages of MIL-STD-883.

Table 2 - ESD SENSITIVITY CLASSIFICATION

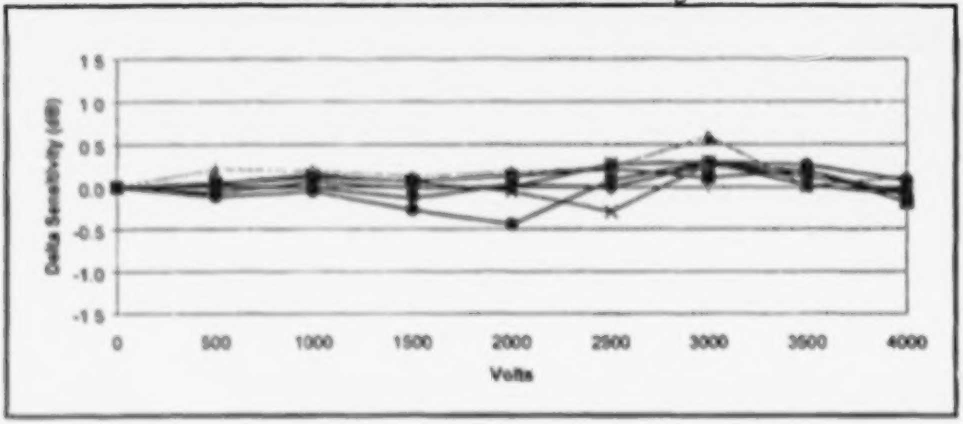
Lucent Designation	Withstand Threshold (Volts)	MIL-STD-883 Classification
Class 0	0-199	1
Class I	200-499	1
Class II	500-1999	1
Class III	2000-3999	2
Class III	4000 and above	3

Six transmitters and six receivers were tested to determine the ESD HBM withstand voltage. Both transmitter and receiver modules passed a withstand threshold voltage of ±4000 V.

Results of Transmitter HBM ESD Testing



Results of Receiver HBM ESD Testing



3.3.3.3 Flammability

Materials used in the construction of the transmitter and receiver modules have been assessed to Underwriters Laboratories flammability requirement UL 94-V1 and ASTM D-2863 Oxygen Index greater than 28% as defined by Bellcore. Transmitters and receivers are manufactured with multiple fiber types; devices that use Hytrel fiber, are non-compliant to Bellcore requirements. Hytrel fiber is used throughout the optoelectronics industry for many different applications and has been accepted for use even though the fiber does not meet the requirements stated above. All other materials used in the construction of the transmitter and receiver modules meet these stated flammability requirements.

3.3.4 ADDITIONAL SPECIAL TESTS

3.3.4.1 Solvent Resistance

The solvent resistance test is performed in accordance with MIL-STD-883, Method 2015. This test is designed to verify that component markings will not become illegible or that labels used on components will not become illegible or detached when exposed to the solvents typically used to clean printed wiring board assemblies.

Five receivers were evaluated for solvent resistance. No failure conditions were noted.

3.4 TRANSMITTER AND RECEIVER SURVEILLANCE PROGRAM

In addition to the qualification program for this product, Lucent Technologies also has in place a manufacturing surveillance test program that requires periodic reviews of critical manufacturing processes associated with the product and a product surveillance test plan which periodically subjects randomly selected product to a suite of tests designed to ensure that the product continues to meet established quality and reliability goals. Tables 3 and 4 list the surveillance tests and sampling frequency required by the transmitter and receiver product surveillance plans.

Table 3

1241-Type and 1243-Type Surveillance Test Plan

Test Conditions: -40°C, 25°C and 85°C

TEST	CONDITIONS	LTPD	MAXIMUM SAMPLE INTERVAL
Temperature Cycle	-40°C to +85°C, 10 cycles	20%	1 Month
Mechanical Shock	Unbiased, 5 blows, 500g, 6 axis, half sign, 0.5 ms	20%	3 Month
High Temperature Aging with Bias	60 °C, 96 Hours	20%	3 Month
Design Checks	Optical & Electrical Parameters at Vcc(MIN), Vcc(MAX), Tc = -40°C, Tc=+85°C	20%	3 Month

Table 4

1340-Type and 1345-Type Surveillance Test Plan

Test Conditions: -40°C, 25°C and 85°C

TEST	CONDITIONS	LTPD	MAXIMUM SAMPLE INTERVAL
Temperature Cycle	-40°C to +85°C, 10 cycles	20%	1 Month
Mechanical Shock	Unbiased, 5 blows, 500g, 6 axis, half sign, 0.5 ms	20%	3 Month
High Temperature Aging with Bias	60 °C, 96 Hours	20%	3 Month
Design Checks	Optical & Electrical Parameters at Vcc(MIN), Vcc(MAX), Tc = -40°C, Tc=+85°C	20%	3 Month

4.0 SUMMARY AND RELIABILITY ESTIMATES

An overview of the Lucent Technologies Qualification program for the 1241-Type and 1243-Type transmitter modules and the 1340-Type and 1345-Type receiver modules has been presented with a focus on the plan specifics and the results of the qualification testing. The qualification plan for this device was designed to ensure that the transmitter and receiver modules meet the rigorous reliability requirements of Lucent Technologies as well as the requirements of our customers. The qualification of these modules also meets the intent of the uncontrolled environment requirements set forth in Bellcore TA-TSY-000983[2]. Qualification reports for the laser and detector packages are available upon request.

Using data derived from the qualification program, the Lucent Reliability Information Notebook and other sources, a reliability estimate for the transmitter and receiver modules has been developed. These reliability estimates are shown in Tables 5 and 6.

Table 5

1241-Type and 1243-Type Transmitter Reliability Estimate

PARAMETER	**MEASURED VALUE**
	1.0×10^6 Hours
Standard Deviation (σ)	~ 1.0
Maximum Wear-Out Failure Rate (λ_{max})	200 FITs
Wear-Out Activation Energy (Ea)	~0.6 eV
Random Failure Rate (λ_R) @ 40°C	625 FITs
Random Failure Activation Energy (Ea)	0.35 eV^2

Table 6

1340-Type and 1345-Type Receiver Reliability Estimate

PARAMETER	MEASURED VALUE
Median Life @ 40°C	—
Standard Deviation (σ)	—
Maximum Wear-Out Failure Rate (λ_{max})	No Wear Out
Wear-Out Activation Energy (Ea)	—
Random Failure Rate (λ_R) @ 40°C	310
Random Failure Activation Energy (Ea)	0.35 eV^2

5. MISCELLANEOUS

5.1 Transmitter and Receiver Shipping Container

The transmitter and receiver modules are shipped in a container (box) that will protect the device from damage due to normal handling, shipping, storage and ESD damage, as specified by Bellcore, for a period of up to one year. The materials used in the package will not crumble, flake, outgas, powder or shred.

5.2 Labeling

The package containing the product will be marked with the Lucent Technologies logo, Lucent Technologies part number and appropriate warning labels regarding ESD and handling.

The transmitter and receiver modules will be marked with the Lucent Technologies logo, the part number and a CODE 39 barcoded label, with human readable text, which combines the device serial number and the date of manufacture code. The information is thermally printed on this label which is manufactured from a white polyester film material having a permanent acrylic pressure sensitive adhesive and a top surface specifically formulated for thermal transfer printing. The format of this label is as follows:

> YWWXXXX where Y is the year, i.e., 8=1998, 9=1999, etc., and WW is the calendar week of manufacture within the year. XXXX will be a unique number for product manufactured in any particular week.

REFERENCES

1. Bellcore Technical Reference TR-NWT-000468, "*Reliability Assurance Practices for Optoelectronic Devices in Interoffice Applications*", Issue 1, December 1991.

2. Bellcore Technical Advisory TA-NWT-000983, *Reliability Assurance Practices for Optoelectronic Devices in the Loop Applications*,'Issue 2, December 1993.

3. Bellcore Technical Advisory TA-NWT-000253, "*Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria*", Issue 8, October 1993.

4. ANSI T1.117-1991, "*American National Standard for Telecommunications-Digital Hierarchy-Optical Interface Specifications (SONET) (Single Mode-Short Reach*)".

5. ITU-T (Formerly CCITT), Recommendation G.957, "*Optical Interfaces for Equipments and Systems Relating to the Synchronous Digital Hierarchy*".

6. ITU-T (Formerly CCITT), Recommendation G.958, "*Digital Line Systems Based on the Synchronous Hierarchy for use on Optical Fibre Cables*".

7. Military Standard, MIL-STD-883E, "*Test Methods and Procedures for Microelectronics*"

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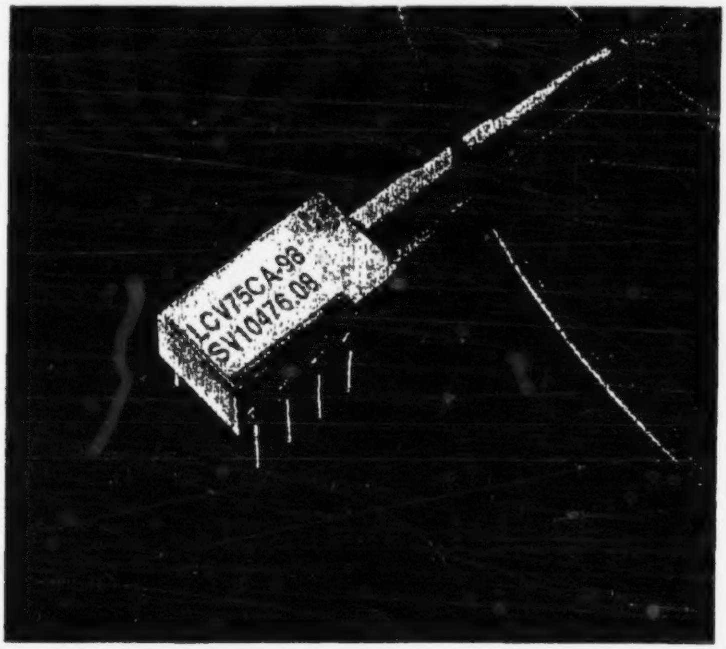
MINI DIL LASER MODULE QUALIFICATION REPORT

QR1241/96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ABSTRACT

This report documents the results of the qualification programme conducted on the LCV75-98 series Mini DIL Laser Module. These results demonstrate that the module meets the qualification test requirements to stringent Bellcore standards for use in either 'Controlled' or 'Uncontrolled Environments'. These relevant standards being:-

Bellcore TR-NWT-000468, "Reliability Assurance Practices for Optoelectronic Devices in Interoffice Applications" - Controlled Environments.

and

Bellcore TA-NWT-000983, "Reliability Assurance Practices for Optoelectronic Devices in Loop Applications" - Uncontrolled Environments.

Although the data set out in this report references the tests required for Bellcore 983 those tests exceed the Bellcore 486 requirements in every case and as such qualifies the device for use in either 'Controlled" or "Uncontrolled" environments.

Included, for information purposes, are results from extended verification and overstress testing performed prior to, and during formal qualification, These results show the ongoing capability of the module far exceeds the Qualification requirements.

1.0 INTRODUCTION

The purpose of this programme was to demonstrate that the LCV75-98 series of Mini Dil Laser Modules meets the qualification test requirements of Bellcore TR-NWT-000468 and TA-NWT-000983.

The Mini DIL Laser Module is a high performance laser module which has been specifically designed for use in junction, access and local area networks. The module is an 8 pin, dual in line, hermetic package with an integral silicon based optical platform. This platform comprises a 1300nm FP laser diode controlled by the photocurrent from a back facet monitor photodiode. The light output of the laser diode is tightly coupled to a highly stable, fibre alignment system. The fibre exits the package via a hermetically sealed feedthrough tube. Samples submitted for this qualification programme covered main power levels of 0.1, 1.0 and 2.0mW.

The technical reference documents, TR-NWT-000468 and TA-NWT-000983 have been prepared by Bellcore (Bell Communication Research Inc.), to provide the optoelectronic device industry with a set of generic reliability requirements for telecommunications equipment, which are considered to be appropriate in the use of these devices in interoffice environments and remote terminal or uncontrolled environments. One of the major elements covered in this document is device qualification. Device qualification has two primary purposes. Firstly to confirm the ability of the device to meet the equipment manufacturer's performance requirements, and secondly, to

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verify its long term performance. Testing demonstrates conformance by Characterisation and Reliability Testing.

The test programme undertaken included characterisation, which involves the measurement of optical and electrical parameters over the operating temperature range, and reliability testing comprising three main groups:- Endurance, Mechanical/Physical Integrity and Special Tests. A summary of these tests is shown in Section 2, and the results of the individual tests presented in Sections 3 to 14. The appendices contain the results of extended and overstress testing.

The Mini DIL Laser Module, in common with other Nortel products, is subject to continuous improvement to meet the demanding needs of the telecommunications industry. This is reflected in the latest LCV75-98 data sheet, in which fibre power levels of 0.1mW to 2.0mW are specified options.

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2.0 SUMMARY OF TEST RESULTS

GROUP	TEST	REFERENCE	CONDITION	SS	C	QTY FAIL	See Sect.
Characterisation				20	0	0	3.0
Endurance	Accelerated Ageing	TA-NWT-000983	85°C, Constant Im 2000 hours 5000 hours	25	-	-	4.0
	Temperature Cycling	MIL-STD-883 Method 1010	-40°C to +85°C 500x pass/fail 1000x info	11	0	0	5.0
	Storage Low Temperature (recommended) High Temperature		 -40°C, 2000 hours 85°C, 2000 hours	 25 11	 0 0	 0 0	 6.0 7.0
	Cyclic Moisture Resistance	MIL-STD-883 Method 1004		11	0	0	8.0
Mechanical Integrity	Mechanical Shock	MIL-STD-883 Method 2002	Condition B 1500 G, 0.5ms 5 times/ axis	11	0	0	9.0
	Vibration	MIL-STD-883 Method 2007	Condition A 20 G, 20-20,000Hz 4 min./cycle 4 cycles/axis	11	0	0	9.0
	Fibre Pull		1 Kg, 3times, 10 seconds	11	0	0	9.0
	Solderability	MIL-STD-883 Method 2003	No Steam Ageing	11	0	0	10.0
	Thermal Shock	MIL-STD-883 Method 1011	0°C to 100°C	11	0	0	10.0
	Lead Integrity (additional test)	MIL-STD-883 Method 2004 Conditions A, B1, B2.		11	0	0	10.0
Special Tests	Internal Moisture	MIL-STD-883 Method 1018	≤ 5000 ppm	11	0	0	11.0
	Flammability	TR-NWT-000078		-	-	-	12.0

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GROUP	TEST	REFERENCE	CONDITION	SS	C	QTY FAIL	See Sect.
	ESD	TR-NWT-000870	> 500 volt objective	6	0	0	13.0
Additional Tests	Damp Heat (for info only)	MIL-STD-202 Method 103	40°C/95% RH, 56 days	13	-	0	14.0

SS = Sample Size C = Number of Failures Allowed

Summary of Over Stress Tests

GROUP	TEST	REFERENCE	CONDITION	SS	C	QTY FAIL	See Sect.
Verification	Temperature Cycling	MIL-STD-883 Method 1010	-40°C to +85°C 7000x	9	-	-	App.1
			-55°C to +100°C 3000x	9	-	-	App.1
	Storage Low Temp.	-	-40°C, 7000 hours	9	-	-	App.2
	High Temp.	-	+85°C, 7000 hours	9	-	-	App.2

The allowable change limits applied over all the relevant test legs were as follows;

$\Delta I_{th} \leq 5\%$

$\Delta I_m \leq 10\%$

$\Delta Po \leq 10\%$

3.0 CHARACTERISATION

The key parameters of the modules are 100% electrically tested and have been fully characterised over the operating temperature range of -40 to 85°C. Results confirm device performance is in line with the LCV75-98 Data Sheet.

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4.0 ACCELERATED AGEING

Twenty five devices were subjected to the accelerated ageing test under the following conditions:-

Mounted on Temperature Controlled Heater Bars

Test Condition:	85°C Case Temperature
	Duration = 5000 hours
	Constant Im
In-situ tests:	If = Laser Current (mA)
	Im= Monitor Current (μA)
	Po= Output Power (mW)

The intent of Accelerated Ageing is to demonstrate long-term reliability of the device and consequently no sample acceptance figure is defined by Bellcore for this test.

Conclusion:

There have been no failures as a result of this accelerated aging. A plot of drive current from insitu measurements over the 5000 hours period is shown in Figure 1. Degradation rates are low and the device is considered to have passed the requirements of Bellcore TA-NWT-000983.

Additional Data and Analysis:

In addition to the 85°C test, devices have been aged at 70°C and 55°C and plots of drive current from the insitu measurements at all three temperatures is shown in Fig. 1. Life test at the alternative temperatures is to show the performance of the device at typical operating temperatures. Analysis has been carried out on this data to allow extrapolation of the degradation trends to determine the lifetime of the devices and to allow activation energies to be calculated. The extrapolated time to failure (TTF) of the device is considered to be the time for the drive current to increase by 50% from the initial value and used a linear-linear fit. Further inspection of the data reveals the degradation to be sublinear and hence the linear-linear fit is considered to be worst case. A log-normal lifetime plot of these extrapolations at 85, 70 and 55°C is in Figure 2 which also shows a summary of Median Life (ML), dispersion and time for 1% and 5% wear out failures at the three life test temperatures.

Wearout failure rate:

Applying the Arrhenius relationship to the median lifetimes at the three life test temperatures gave an average activation energy for drive current wear out of 0.44 eV. This activation energy and wearout statistics (Fig. 2) have been used to compile the Bellcore reliability table in Figure 3.

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Figure 1 : Accelerated Aging Insitu Plots

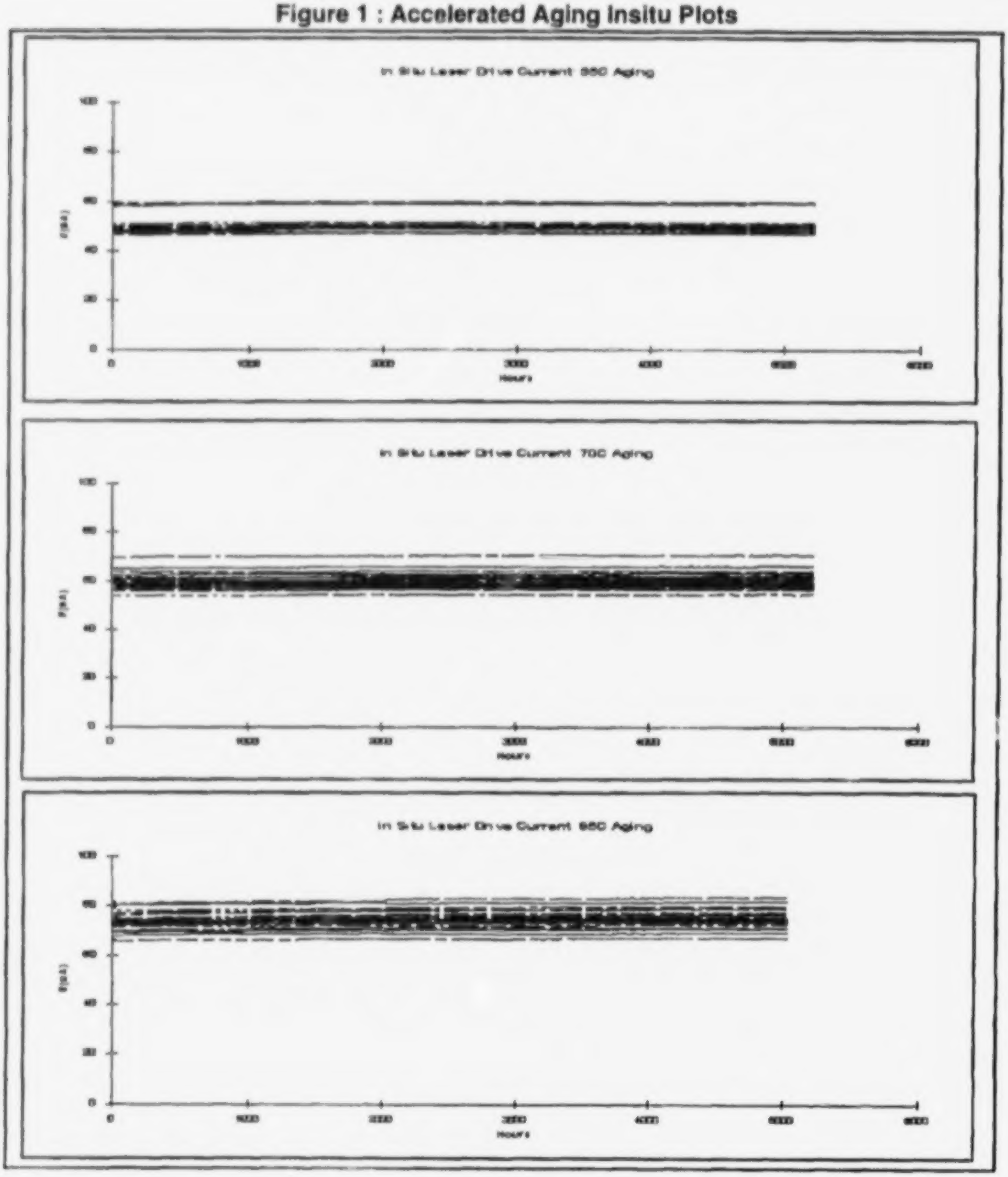

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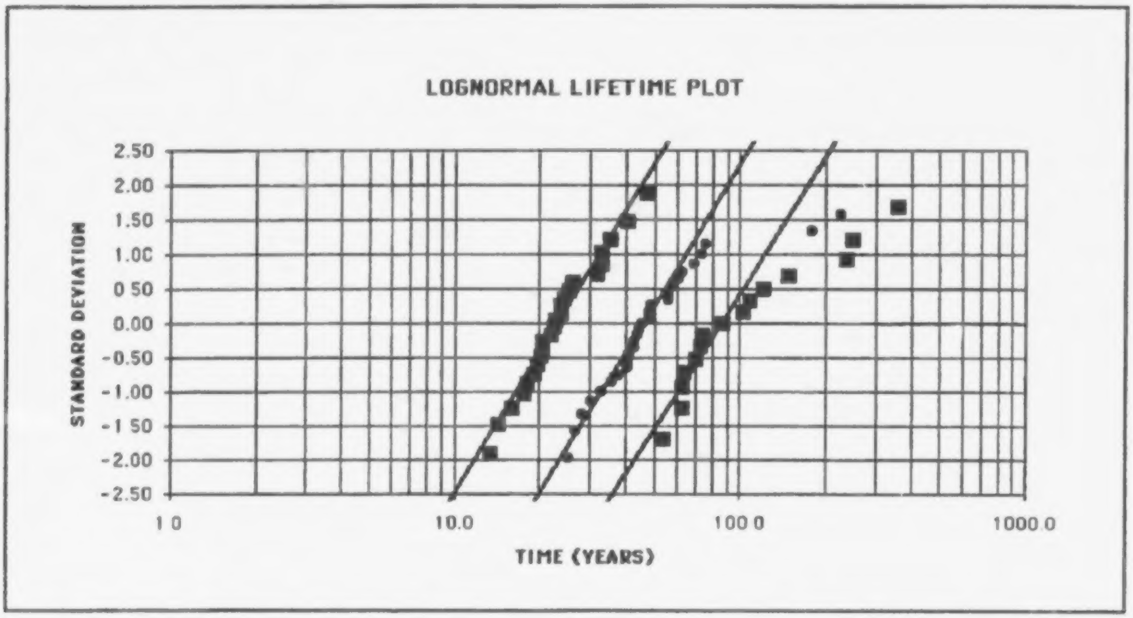
Figure 2 : Log normal plot of calculated time to failure (wearout) Mini DIL



	85°C	70°C	55°C
Median life in years	23.4 yrs	46.8 yrs	87.2 yrs
Dispersion	0.33	0.34	0.35
Time to 1% failures in years	10.7 yrs	21.4 yrs	38.8 yrs
Time to 5% failures in years	13.5 yrs	26.9 yrs	49.2 yrs

Note: Temperatures above are mean operating temperatures over life.

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Random Failure Rate:

The random failure rate in FITS has been calculated from the total number of life test hours accumulated to date. At present over 220 devices have undergone life test covering a temperature range of 55°C to 100°C.

The total component life test hours achieved including chip on carrier data is >3.0E6 hours. Use of the Bellcore default activation energy of 0.35eV yields a random failure rate for the Mini DIL laser of 355FITS @ 60°C, 163FITS @ 40°C and 85FITS @ 25°C. These figures are limited by the number of component hours achieved to date. The actual failure rate is expected to be lower than this value. This is based on increasing hours, the excellent package stability and the absence of significant random failures in this laser diode structure. Experience with other platforms confirms that the early estimates of random failure are pessimistic. Life testing continues and further analysis will be performed as appropriate.

Figure 3 shows the wear out and random reliability information in the format recommended by Bellcore at temperatures of 60, 40 and 25°C.

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Figure 3 : FIT Table

Reliability data for Mini DIL Laser

	Based on drive current @ constant Im			
	60°C	**40°C**	**25°C**	
Median Life	69.2	184	418	**years**
Dispersion	0.35	0.35	0.35	
Wear out failure rate at:-				
operating time of 5 years	0	0	0	**FITS**
operating time of 10 years	0	0	0	**FITS**
operating time of 20 years	11.1	0	0	**FITS**
Wearout activation energy**	0.44	0.44	0.44	**eV**
Random failure rate* (60% CL)	355	163	85	**FITS**
MTTF* (60% CL)	322	700	1344	**years**
Activation Energy***	0.35	0.35	0.35	**eV**

* Includes Chip on Carrier data and is limited by low number of device hours

** Calculated from median lives in Figure 1.

*** Default Value

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5.0 TEMPERATURE CYCLING

Eleven devices were subjected to 100, 500 and 1000 temperature cycles to the conditions specified in MIL-STD-883, Method 1010, Condition A as indicated below:-

Test Condition :	Devices non-operating -40°C to +85°C Temperature Range 15 minute soak time
Measurements:	0, 10, 50, 100, 200, 300, 500, 1000x
Requirements :	100x Pass / Fail for TR-NWT-000468 500x Pass / Fail for TA-NWT-000983 1000x for info only

Results:

The Bellcore change limit over temperature cycle for coupling efficiency is ±10%. Reference to the following data indicates that the maximum changes in fibre power at 100 and 500 cycles were within +5% and -7%, whilst the maximum changes observed in monitor current were between +4% and -7%. Refer to Figures 4 and 5 for graphical data.

Conclusions:

The laser module meets the Temperature Cycle requirements of Bellcore TA-NWT-000983.

Additional Data:

Temperature cycle results from extended verification testing are shown in Appendix 1. Figures 16 and 17 set out the data for 9000 cycles between -40°C and 85°C and 3000 cycles between -55°C and 100°C respectively. Both these graphs show that the inherent stability of the optical train during tests that far exceed the requirements of Bellcore TA-NWT-000983.

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Figure 4 : Temperature Cycle -40°C to +85°C

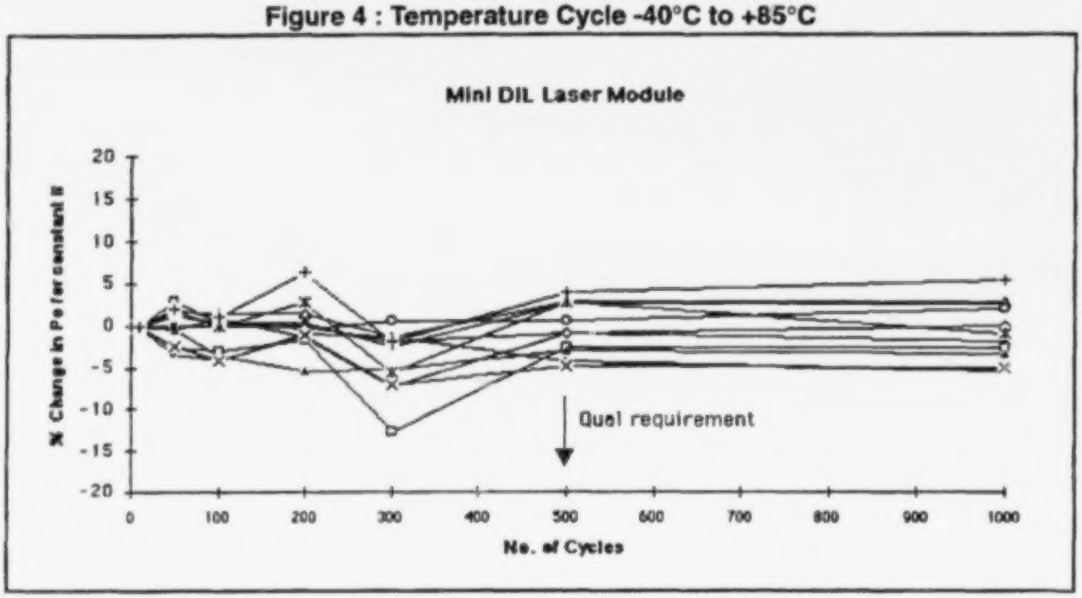
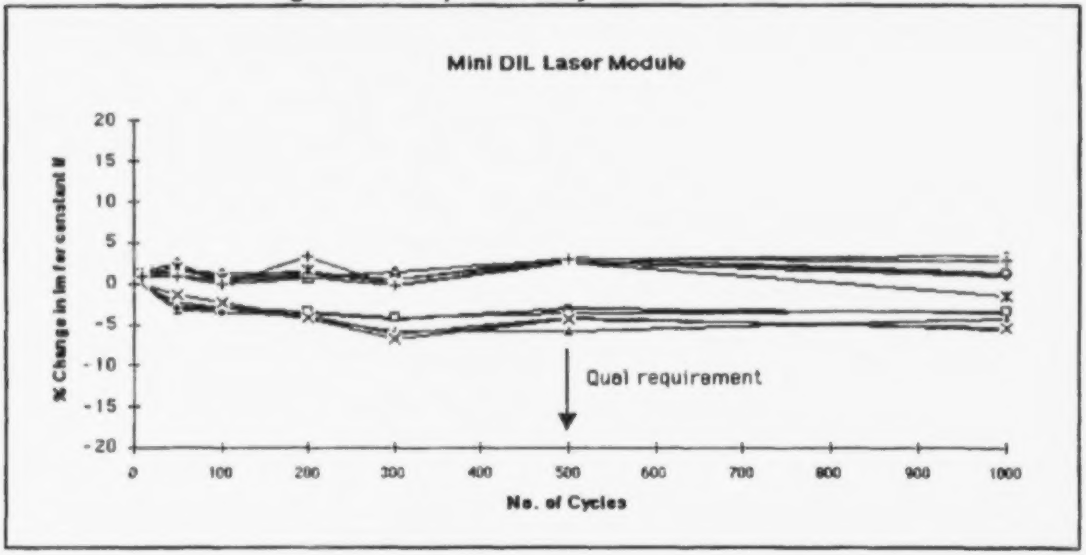


Figure 5 : Temperature Cycle -40°C to +85°C



6.0 LOW TEMPERATURE STORAGE

Twenty Five devices have been subjected to 3300 hours at -40°C. The Bellcore 983 requirement is 2000 hours.

Results:

The maximum changes in fibre power after 3300 hours was +5.8% and -5.6%. The monitor current showed maximum changes of +1.0% and -6.3%. These results are shown in Figures 6 and 7 and demonstrate that the product meets the ±10% requirements of Bellcore 983.

Conclusion:

The laser module meets the Low Temperature Storage requirements of Bellcore TA-NWT-000983.

Additional Data:

Low temperature storage results from extended product verification testing are shown in Appendix 2, Figure 18 and show no significant changes in optical coupling up to 9000 hours (first 1000 hours at -40°C and the remainder which was at -55°C). Both these graphs show that the inherent stability of the optical train during tests that far exceed the requirements of Bellcore TA-NWT-000983.

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Figure 6 : Low Temperature Storage -40°C

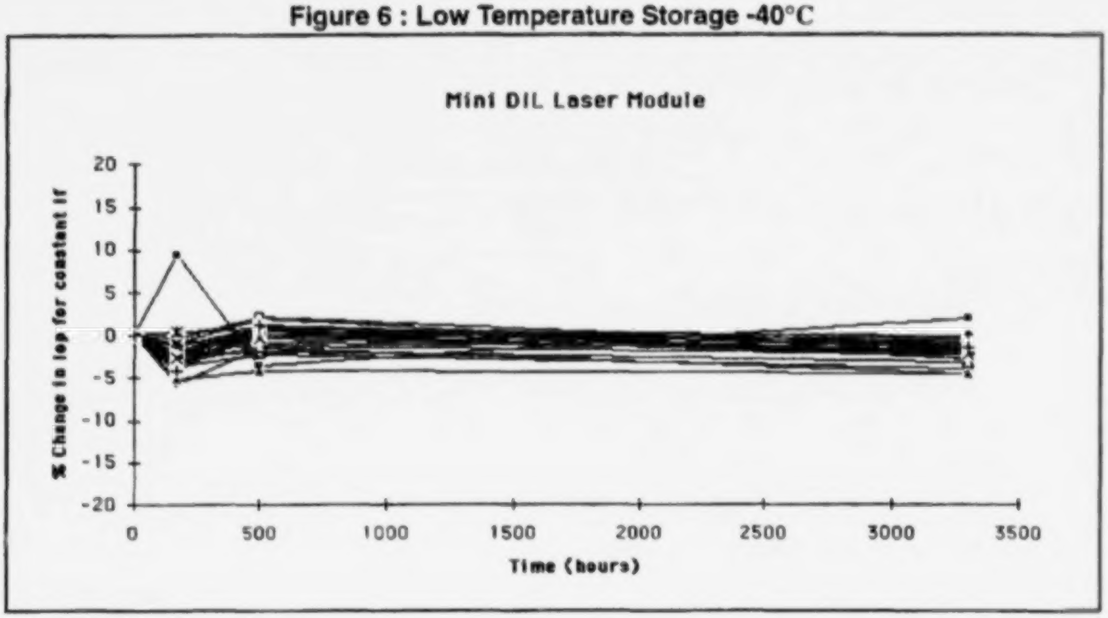
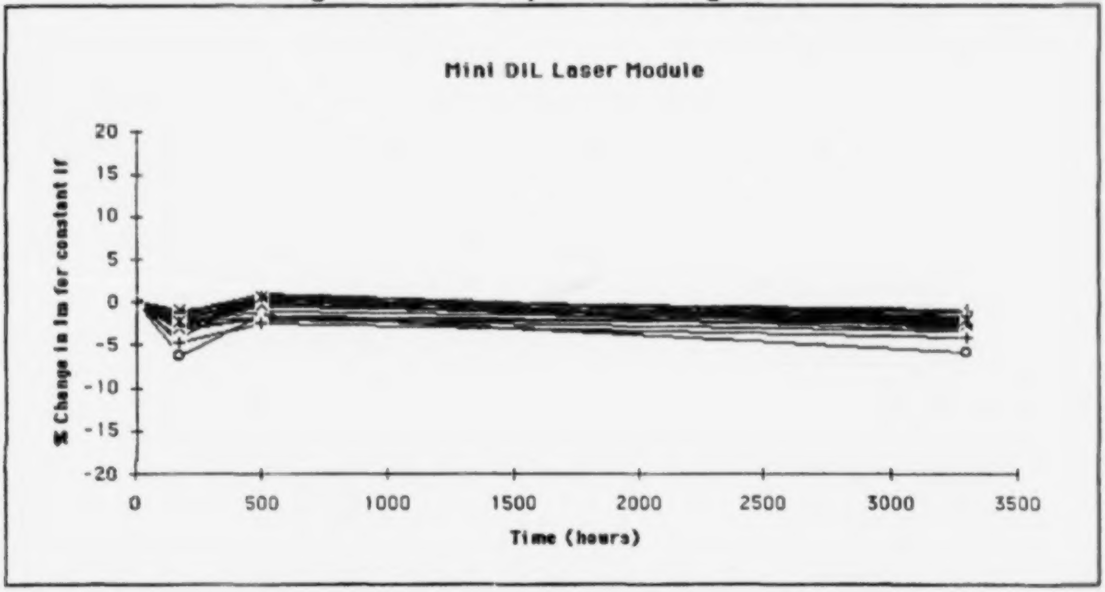


Figure 7 : Low Temperature Storage -40°C



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7.0 HIGH TEMPERATURE STORAGE

Eleven devices have been subjected to the High Temperature Storage test for 5000 hours at +85°C. The Bellcore requirement is 2000 hours.

Results:

Maximum fibre power changes of 1% and -6% were measured after 5000 hours and graphical data is given in Figure 8. Monitor current changes varied between 0% and -7%, and are given in Figure 9. This demonstrates that the product meets the ±10% requirements of Bellcore 983.

Conclusion:

The laser module meets the High Temperature Storage requirements of Bellcore TA-NWT-000983.

Additional Data:

High temperature storage results from extended product verification testing are shown in Appendix 2, Figure 19. Devices were run for 1000 hours at 85°C followed by 1000 hours at 100°C, then a further 7000 hours at 85°C and remained within Bellcore limits of ±10%.

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Figure 8 : High Temperature Storage 85°C

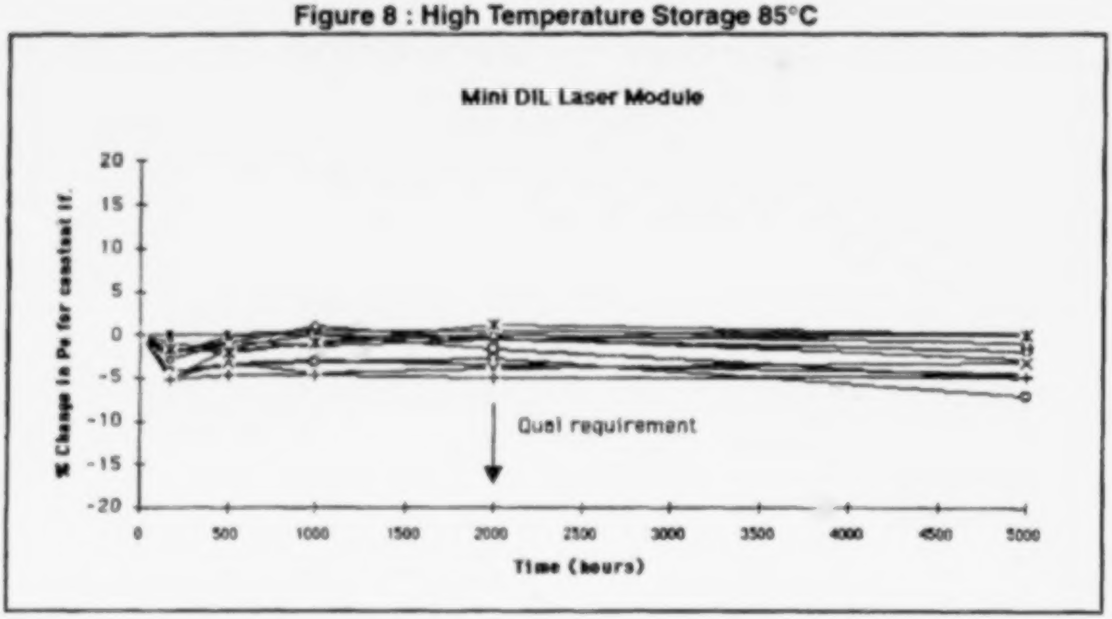
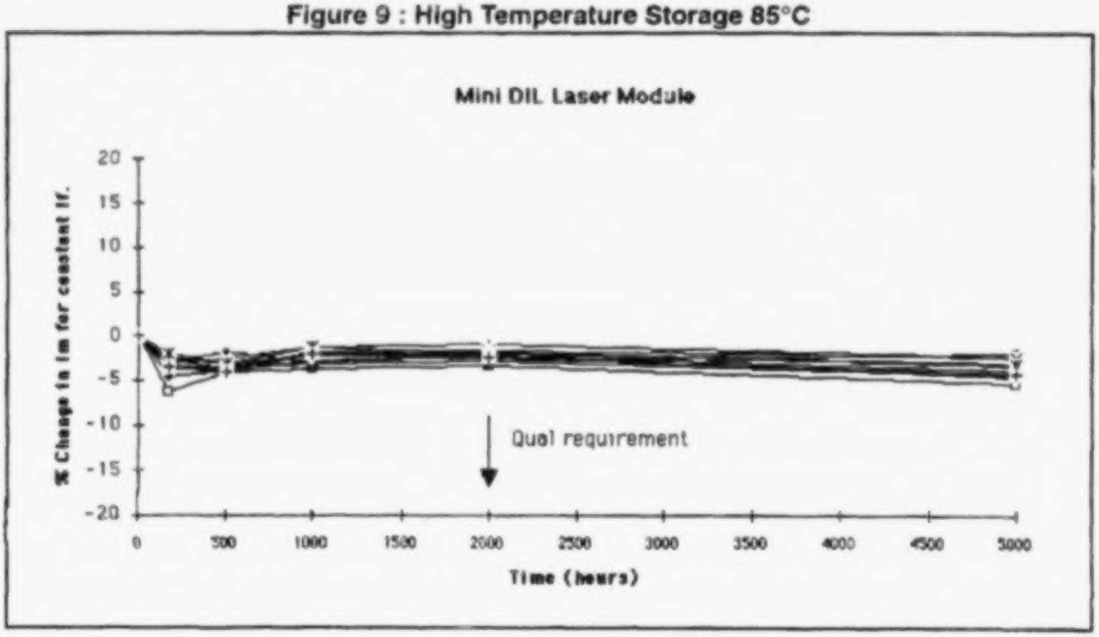


Figure 9 : High Temperature Storage 85°C



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8.0 CYCLIC MOISTURE RESISTANCE

Eleven modules have completed twenty cycles of the moisture resistance test as required by Bellcore 983 for uncontrolled environments followed by Fibre Pull 1Kg, 3 times for 10 seconds.

Results:

A Maximum fibre power change of +10% and monitor current changes varying between ±3% were measured after 20 cycles. The data is shown graphically in Figures 8 and 9. This demonstrates that the product meets the ±10% requirements of Bellcore 983.

Conclusions:

The laser module meets the Cyclic Moisture Resistance requirements of Bellcore 983.

Additional Data:

Fibre pull (1kg, 3 times, 10 seconds) was performed after the cyclic moisture resistance leg. Figures 8 and 9 show that the fibre robustness was not affected by the test.

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Figure 10 : Cyclic Moisture Resistance Test

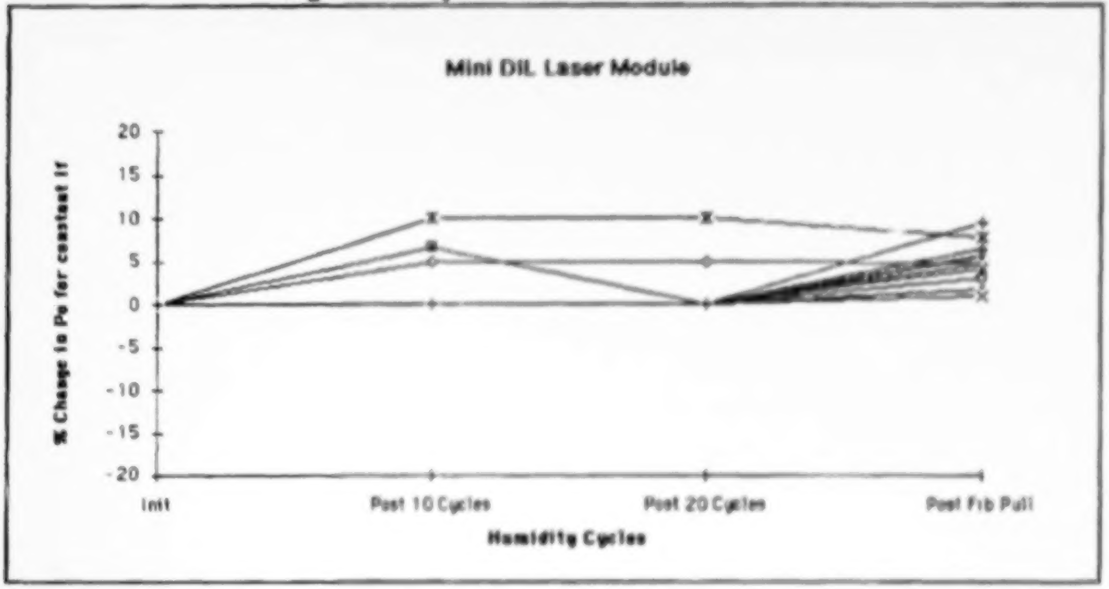
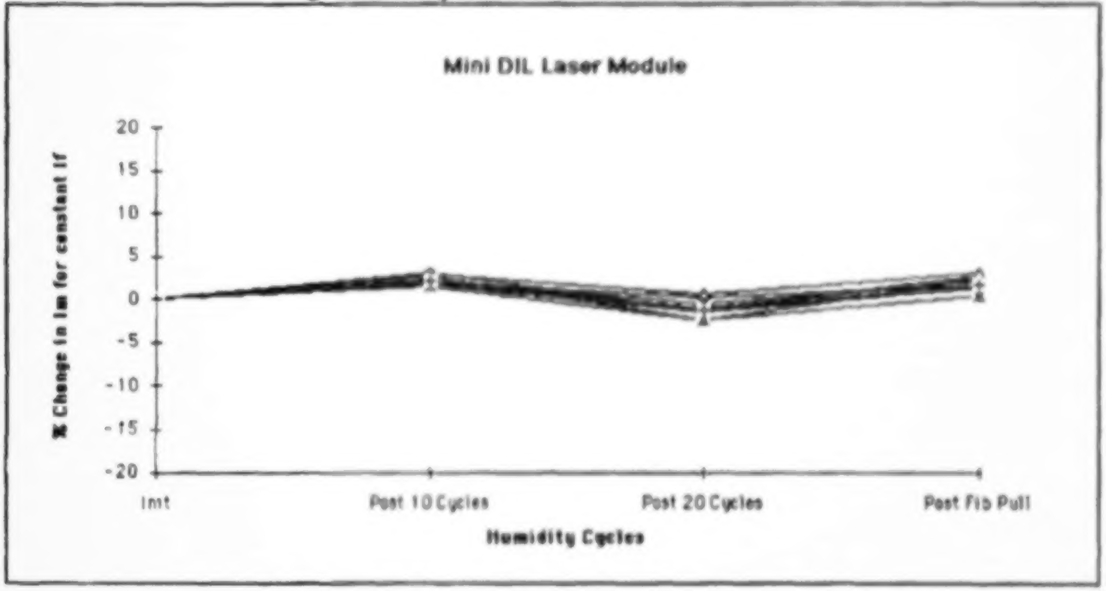


Figure 11 : Cyclic Moisture Resistance Test



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9.0 MECHANICAL INTEGRITY

Fibre Pull, Mechanical Shock and Vibration tests were performed sequentially using the same samples. Results for all three tests are shown in graphical form in Figures 12 and 13.

Fibre Pull

1Kg, 3x, 10 seconds.

Pre and Post electro-optical measurements were performed on the devices subjected to a fibre pull of 1kg, 3 times for a minimum duration of 10 seconds, in a direction coaxial with the fibre as it exits the module package. The maximum change in fibre power of 4% is close to the measurement repeatability and demonstrates the effectiveness of the fibre retention design to withstand external forces applied to the fibre pigtail.

Mechanical Shock

MIL-STD-883, Method 2002, Condition B, 1500g, 0.5ms, 5 times / axis. (These devices have been tested to the more severe 1500g objective of Bellcore rather than the 500g requirement.)

Each of the eleven samples were subjected to five shock pulses of 1500g, 0.5ms duration in each of the three orthogonal axes and in both directions - a total of 30 shocks.

Maximum changes in fibre power were +3% and -3% and in monitor current were +2% and -5%. These changes underwrite the inherent integrity of the mechanical structure of the module and demonstrates conformance to the Bellcore document.

Vibration

MIL-STD-883, Method 2007, Condition A, 20g, 20-2000Hz, 4 min/cycle, 4 cycle/axis

Maximum changes in fibre power over the leg were +3% and -4% and in monitor current were +3% and -4%. These changes underwrite the inherent integrity of the mechanical structure of the module and demonstrates conformance to the Bellcore document.

Conclusion:

The laser module meets the Bellcore TA-NWT-000983 requirements for Fibre Pull, Mechanical Shock and Vibration testing.

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Figure 12 : Mechanical Integrity

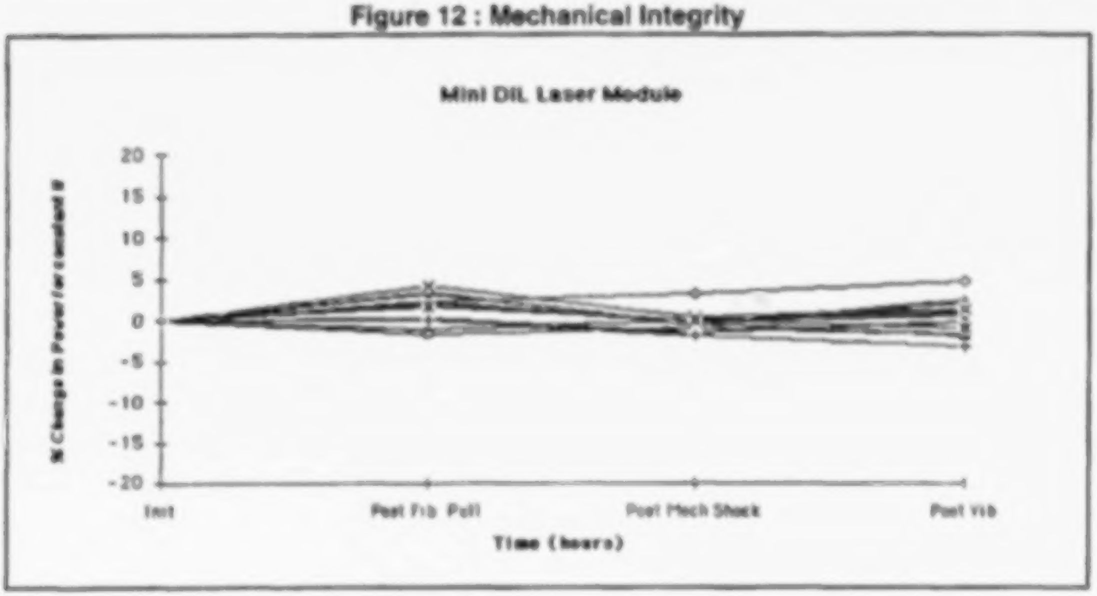
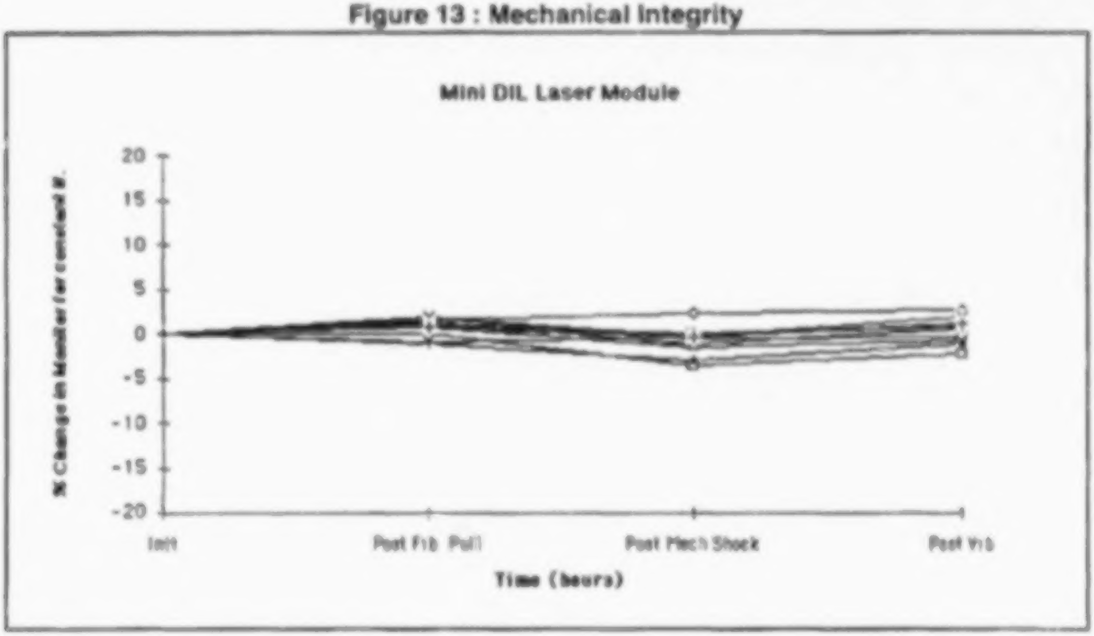


Figure 13 : Mechanical Integrity



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10.0 SOLDERABILITY, THERMAL SHOCK AND LEAD INTEGRITY

Solderability, Thermal Shock and Lead Integrity tests were performed sequentially using the same samples. The hermiticity of the devices was measured pre-test, and after the Thermal Shock and Lead Integrity legs.

SOLDERABILITY

Tests were conducted in accordance with MIL-STD-883 method 2003, with:-

No Steam Ageing

Type R Flux

60/40 tin lead solder

Solder temperature 230°C

10x magnification visual examination

Results:

All the leads had at least 95% coverage of solder coating which meets the requirements of the specification.

THERMAL SHOCK - LIQUID TO LIQUID

Eleven devices were subjected to MIL-STD-883, Method 1011, Condition A, non-operating. The temperature extremes were 0°C and 100°C, the devices were transferred between these extremes 15 times with a transfer time of less than 10 seconds.

Results:

All units met the hermeticity limits defined in the detail specification for the product - see the table of results below.

LEAD INTEGRITY

Eleven devices were subjected to MIL-STD-883, Method 2004, Conditions A, B1 and B2.

Results:

All units met the hermeticity limits defined in the detail specification for the product - see the table of results below.

Serial Numbers	Pre Test	Post thermal shock	Post Lead Integrity
X10873.02	3E-9	4E-9	4E-9
X10873.04	4E-9	1E-8	5E-9
X10873.03	4E-9	1E-8	5E-9
CC32606.05	2E-9	2E-9	4E-9
X10873.09	2E-9	2E-9	3E-9
X10873.08	2E-9	1E-9	2E-9
CC33079.08	3E-9	4E-9	3E-9
CC33079.07	2E-9	4E-9	3E-9
CC33079.04	4E-9	1E-8	1E-8
CC33079.01	4E-9	6E-9	4E-9
CC33079.02	2E-9	4E-9	2E-9

* Hermeticity post test - Leak rate shall not to exceed 1x10-8 atm. cc/s He.

Conclusion:

The laser module meets the Solderability and Thermal Shock requirements of Bellcore TA-NWT-000983 and an additional lead integrity test to MIL-STD-883 Method 2004.

Additional Tests:

In addition to the module related Solderability and Thermal Shock tests specified, the package has also satisfactorily undergone a separate hermetic qualification programme conducted to Nortel's own corporate standards. This programme includes an assessment of hermeticity after being subjected to the following tests:-

- Lead Integrity (Tension and Stress)
- Resistance to Soldering Heat/Thermal Shock* (MIL883 Method1011 Cond. B)
- Temperature Cycling* (MIL883 Method1010 Cond. C)
- Humidity (MIL202 Method103 70°C 85% RH)

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11.0 INTERNAL MOISTURE

Modules were tested by the mass spectrometer technique as defined in procedure 1 of MIL-STD-883, Method 1018. The maximum allowable water vapour content is 5000ppm.

Results:

The mean moisture content on a sample of 11 devices was 1700ppm and the standard deviation was 800ppm. This demonstrates the stringent level of piecepart and material control, and the high standard of cleanliness which is inherent in Nortel's manufacturing processes.

Conclusion:

The laser module meets the Internal Moisture requirements of Bellcore TA-NWT-000983.

12.0 FLAMMABILITY

An analysis has been completed and is detailed below.

Reference specification:	TR-NWT-000078
	TR-TSY-000357

Requirements: To determine the oxygen index rating of associated combustible materials of the full device as used by the customer. Materials shall have an oxygen index of greater than 28%. Any materials failing to meet this requirement should be reported.

Results:

Materials:-

1. Singlemode Hytrel secondary coated fibre. The oxygen index of this material is of the order of 21%. The material has been subjected to the needle flame test and will sustain a flame. (report THR/94/135).

2. Santoprene 251/80 silicon free Protective boot. UL 94 flame rating 1.39mm V-0, LOI 25%. Data supplied by Advanced Elastomer Systems product data sheet for Santoprene 251/80 thermoplastic rubber.

Conclusion:

The flammability of the external components of the device are confined to the fibre and its associated components and are listed above in line with the requirements of the controlling documentation. The volume of this material is very small compared to the volume content of the expected system into which the device is mounted. As this material is not concentrated in one area, (since the fibre should not be coiled tighter than a radius of 30mm) it is considered to be suitable for use.

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13.0 ESD

Six devices were separately subjected to forward and reverse applications of Electrostatic Discharge according to the Human Body Model defined in MIL-STD-883 Method 3015.3 (NPS25268, Section 4.5.3). To establish the threshold level, device failure was defined as one or more of the following:-

(i) 50% increase in Ith
(ii) Laser facet degradation
(iii) Severe L-I curve distortion (kinks)
(iv) Loss of laser function (esp. loss of defined threshold)
(v) Reverse breakdown voltage less than -1.0 Volts.

6 devices were tested from 200 volts to 2000 volts in various increments:

All devices exceeded the 500 Volt minimum requirement.

14.0 DAMP HEAT

Thirteen devices were tested at 40°C and 95% RH for 56 days. The mini DIL does not have epoxy in the non-hermetic portion of the module and in the optical train. This test was carried out for information only.

Results:

The maximum changes seen in forward current were +5% and -1%. The Monitor current showed maximum changes of +6% and -3%. This data is set out graphically in Figures 14 and 15.

Conclusion:

The parameters measured were within the limits of ± 10%.

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Figure 14 : Damp Heat Test

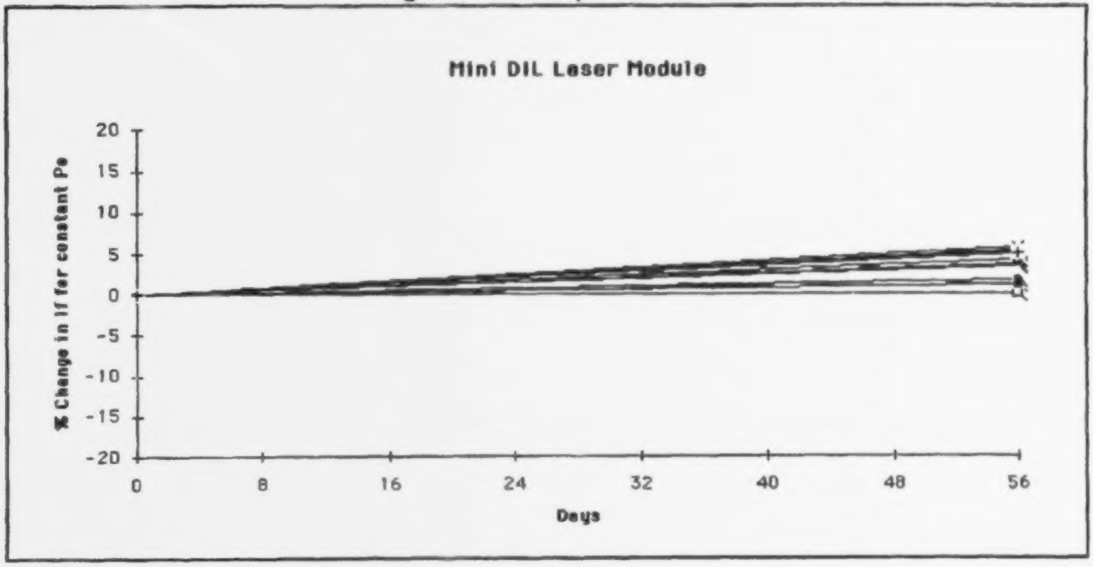
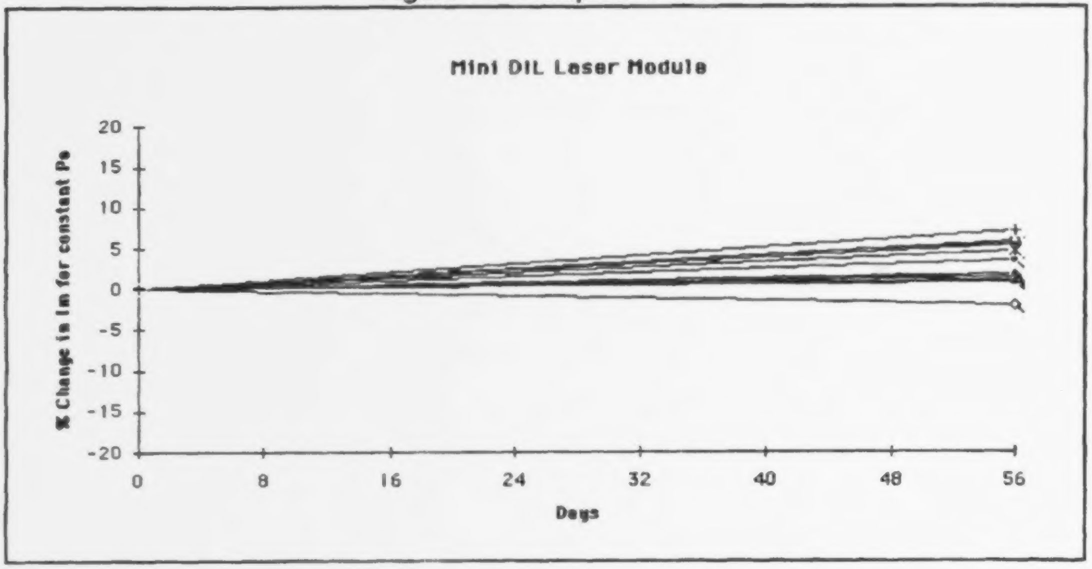


Figure 15 : Damp Heat Test



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15.0 CONCLUSIONS

This report has presented the qualification programme test results for the LCV75-98 series of Mini DIL Laser Modules, and demonstrates that the device meets the Qualification Test requirements of Bellcore TA-NWT-000983, "Reliability Assurance Practices for Optoelectronic Devices in Loop Applications".

The results observed in this report reflect the high stability of the optical train in maintaining coupling efficiency throughout the duration of the stringent Bellcore mechanical, environmental and endurance tests. The inherent long-term reliability of the module has been demonstrated from the Accelerated Ageing data. Additional overstress temperature cycle and storage tests have been performed which show the inherent stability of the optical train. Particular attention is drawn to the temperature cycling results with no significant changes over 9000 cycles -40°C to +85°C and 3000 cycles -55°C to +100°C.

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APPENDIX 1: Temperature Cycling

Product verification testing was carried out to establish platform capability with respect to the stability of the Optical train. A summary of the results of this work is shown in the following Appendices. This work represents the product capability seen prior to formal qualification testing. Product verification build standard is considered representative of product build standard of qualification devices.

Figure 16 : Extended Temperature Cycle 9000 cycles (-40°C to +85°C)

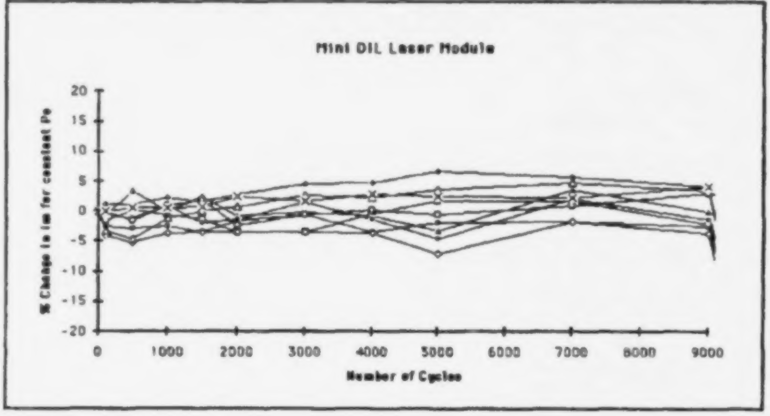
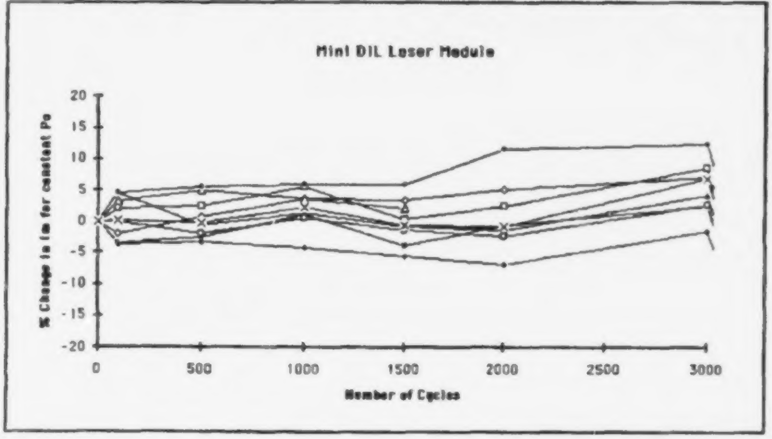


Figure 17 : Extended Temperature Cycle 3000 cycles (-55°C to +100°C)



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APPENDIX 2: Storage

Figure 18 : Low Temperature Storage

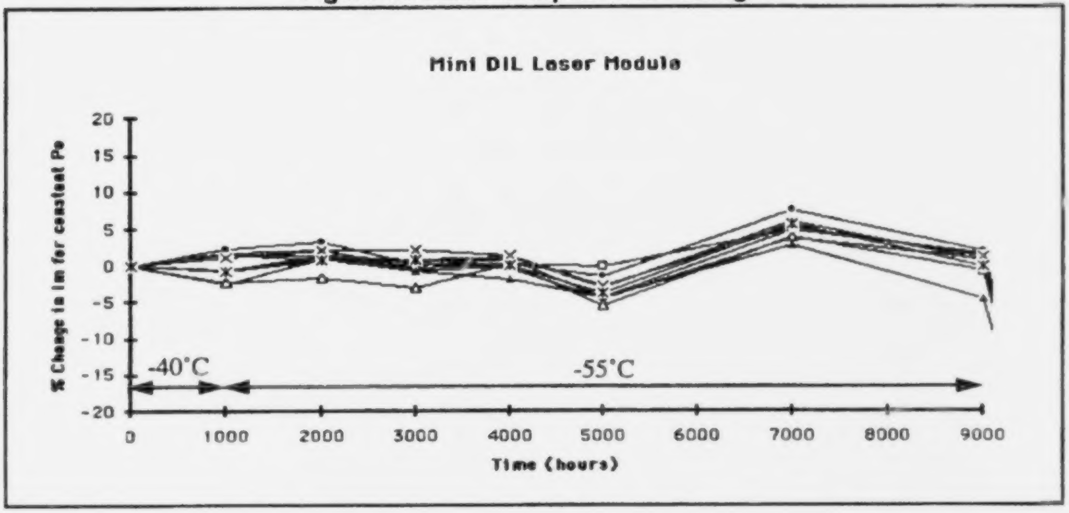
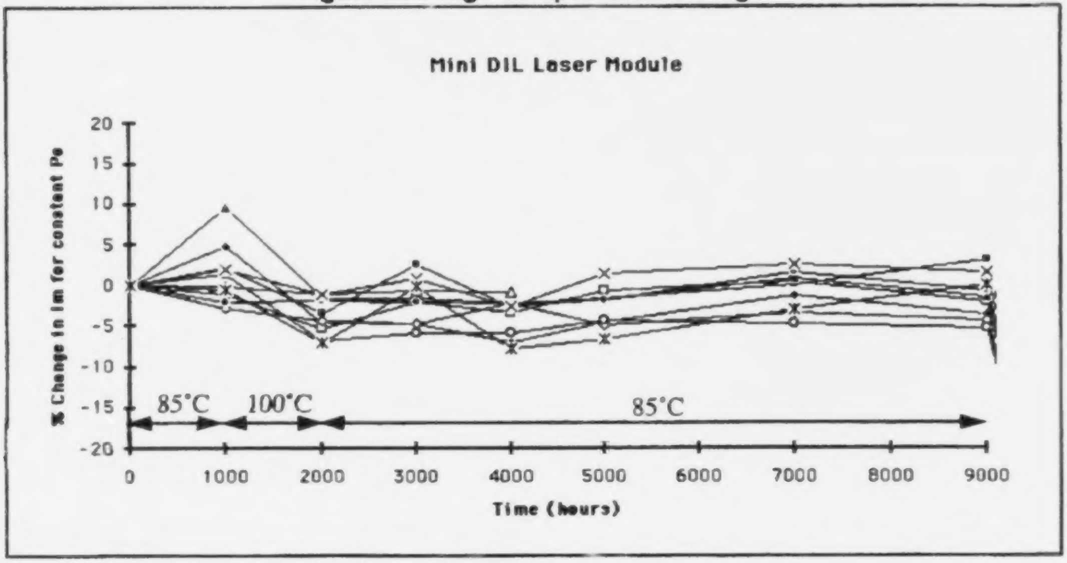


Figure 19 : High Temperature Storage



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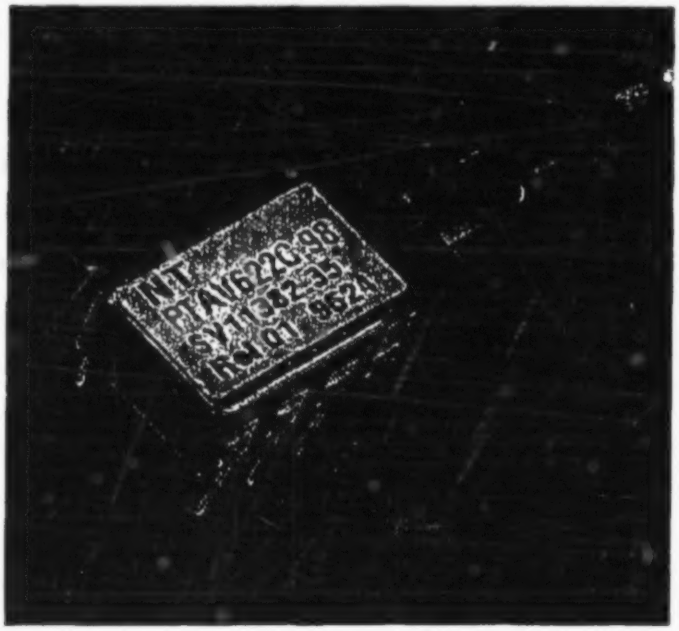
MINI DIL RECEIVER MODULE QUALIFICATION REPORT

QR1313/97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MINI DIL RECEIVER MODULE
QUALIFICATION REPORT QR1313 ISSUE 3.0

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ABSTRACT

This report documents the results of the qualification programme conducted on the PTAV50/155/622 series Mini Dil Receiver Module. These results demonstrate that the module meets the qualification test requirements to stringent Bellcore standards for use in either 'Controlled' or 'Uncontrolled Environments'. These relevant standards being:-

Bellcore TR-NWT-000468, "Reliability Assurance Practices for Optoelectronic Devices in Interoffice Applications" - Controlled Environments.

and

Bellcore TA-NWT-000983, "Reliability Assurance Practices for Optoelectronic Devices in Loop Applications" - Uncontrolled Environments.

Included, for information purposes, are results from extended verification and overstress testing performed prior to and during formal qualification, these results show the ongoing capability of the module against the Qualification requirements.

1.0 INTRODUCTION

The purpose of this programme was to demonstrate that the PTAV50 (NT8W97**) /155 (NT8W95**) /622 (NT8W96**) series of Mini Dil Receiver Modules meet the qualification requirements of Bellcore TR-NWT-000468 and TA-NWT-000983.

The PTAV50/155/622 are high performance receiver modules which have been specifically designed for use in junction, access and local area networks. The module is an 8 pin, dual in line, hermetic package with an integral silicon based optical platform. This platform comprises an 80μm InGaAs REPP and high sensitivity transimpedance amplifier. A highly stable, fibre alignment system is used to couple light to the diode. The fibre enters the package via a hermetically sealed feedthrough tube.

The technical reference documents, TR-NWT-000468 and TA-NWT-000983 have been prepared by Bellcore (Bell Communication Research Inc.), to provide the optoelectronic device industry with a set of generic reliability requirements for telecommunications equipment, which are considered to be appropriate in the use of these devices in interoffice environments and remote terminal or uncontrolled environments. One of the major elements covered in this document is device qualification. Device qualification has two primary purposes. Firstly to confirm the ability of the device to meet the equipment manufacturer's performance requirements, and secondly, to verify its long term performance. Testing demonstrates conformance by Characterisation and Reliability Testing.

The test programme undertaken included characterisation for each of the 3 variants, which involves the measurement of optical and electrical parameters over the operating temperature range, and reliability testing of the PTAV155 device comprising three main groups:- Endurance,

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Mechanical/Physical Integrity and Special Tests. A summary of these tests is shown in Section 2, and the results of the individual tests presented in Sections 3 to 13.

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2.0 SUMMARY OF TEST RESULTS

GROUP	TEST	REFERENCE	CONDITION	SS	C	QTY FAIL	See Sect.
Characterisation				30*	0	0	3.0
Endurance	Accelerated Ageing	TR-NWT-000468	85°C, 1.5x V 5000 hours	25	-	-	4.0
	Temperature Cycling	MIL-STD-883 Method 1010	-40°C to +85°C 500x pass/fail 1000x info only	25	0	0	5.0
	Storage Low Temperature (recommended)		-40°C, 2000 hours	25	0	0	6.0
	High Temperature		85°C, 5000 hours	11	0	0	7.0
	Cyclic Moisture Resistance	MIL-STD-883 Method 1004		11	0	0	8.0
Mechanical Integrity	Mechanical Shock	MIL-STD-883 Method 2002	Condition B 1500 g, 0.5ms 5 times/ axis	11	0	0	9.0
	Vibration	MIL-STD-883 Method 2007	Condition A 20 g, 20-20,000Hz 4 min./cycle 4 cycles/axis	11	0	0	9.0
	Fibre Pull		1 Kg, 3times, 10 seconds	11	0	0	9.0
	Solderability	MIL-STD-883 Method 2003	No Steam Ageing	11	0	0	10.0
	Thermal Shock	MIL-STD-883 Method 1011	0°C to 100°C	11	0	0	10.0
	Lead Integrity (additional test)	MIL-STD-883 Method 2004 Conditions A, B1, B2.		11	0	0	10.0
Special Tests	Internal Moisture	MIL-STD-883 Method 1018	≤ 5000 ppm	11	0	0	11.0
	Flammability	TR-TSY-000078					12.0
	ESD	TR-TSY-000870	> 500 volt objective	6	0	0	13.0

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GROUP	TEST	REFERENCE	CONDITION	SS	C	QTY FAIL	See Sect.
Additional Tests	Damp Heat (for info only)	MIL-STD-202 Method 103	40°C/95% RH, 56 days	13	-	-	App.1

SS = Sample Size   C = Number of Failures Allowed

* Characterisation split equally between PTAV50/155/622

The allowable change limits applied over all the relevant test legs were as follows;

Δ Change in Supply Current ≤ 10%

Δ Change in responsivity ≤ 10%

3.0 CHARACTERISATION

The key parameters of the modules are 100% electrically tested and have been fully characterised over the operating temperature range of -40°C to 85°C. Results confirm device performance is in line with the PTAV50/155/622 Data Sheets.

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4.0 ACCELERATED AGEING

Twenty five devices were subjected to the accelerated ageing test under the following conditions:-

Mounted on Temperature Controlled Heater Bars

Test Condition:	85°C Case Temperature
	Duration = 5000 hours
	Biased at 1.5x Vop
In-situ tests:	Id = Dark Current (nA)
	Icc = Supply Current (mA)
	Vo= Output Voltage (V)

The intent of Accelerated Ageing is to demonstrate long-term reliability of the device and consequently no sample acceptance figure is defined by Bellcore for this test.

Conclusion:

There have been no failures as a result of this accelerated aging and the device is considered to have passed the requirements of Bellcore TA-NWT-000983.

Wearout Failure Rate:

The lifetime of a device would normally be calculated by extrapolating any gradual degradations to their specified failure criteria. When carrying out this analysis on photodiodes two complications can arise. Bellcore 983 advises that care must be taken when calculating the Median Life to ensure identification and exclusion of early failures which do not represent the main population of devices, and also, the time to failure cannot be extrapolated when the end-of-life criterion is a maximum allowed dark current, and the dark current decreases during the life test. In this lifetest the majority of the devices which have undergone accelerated ageing show a decreasing dark current. Therefore no meaningful lifetimes could be calculated from the present data.

Random Failure Rate:

Analysis was carried out using Bellstress/HRD5 data and package reliability estimates to give the random failure rate. These FIT rates are tabulated below for three typical operating temperatures.

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Component	Fits @40°C	Fits @60°C	Fits @85°C	Source
Transimpedance Amplifier	7	-	-	HRD5
Rx PIN	2	-	-	HRD5
Ceramic Caps	18	-	-	HRD5
Subtotal	27	40	87	
Design				
Rx Uncooled Optical Train and package	50	50	50	Estimated
TOTAL	77	90	137	

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5.0 TEMPERATURE CYCLING

Eleven devices were subjected to 100, 500 and 1000 temperature cycles to the conditions specified in MIL-STD-883, Method 1010, Condition A as indicated below:-

Test Condition :	Devices non-operating -40°C to +85°C Temperature Range 15 minute soak time
Measurements:	0, 10, 50, 100, 200, 300, 500 and 1000 cycles
Requirements :	100x Pass / Fail for TR-NWT-000468 500x Pass / Fail for TA-NWT-000983 1000x for info only

Results:

The Bellcore change limit over temperature cycle for coupling efficiency is ±10%. Reference to the following data indicates that the maximum changes in Responsivity at 500 cycles were within ±2%, whilst the maximum changes observed in supply current were between +3.3% and -3.4%. Refer to Figures 1 and 2 for graphical data.

Conclusion:

The receiver Module meets the Temperature Cycle requirements of Bellcore TR-NWT-000983.

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Figure 1 : Temperature Cycle -40°C to +85°C

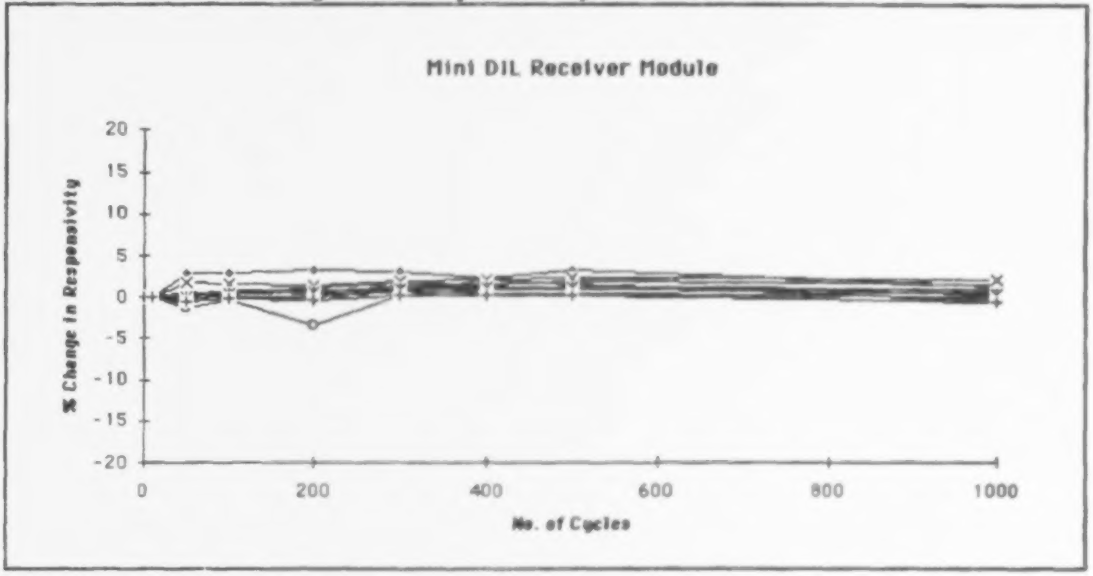
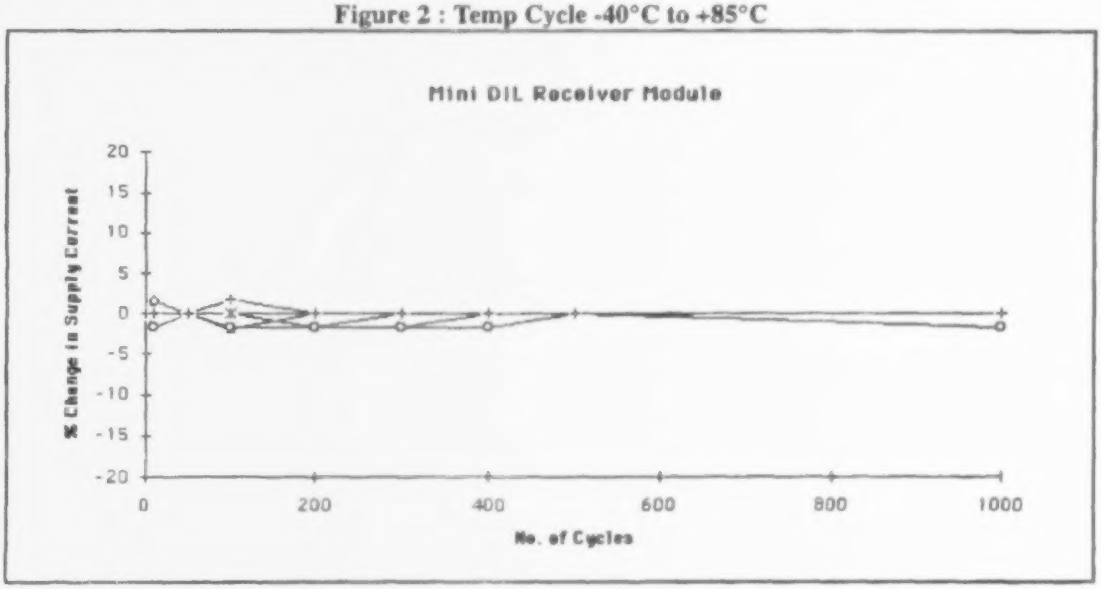


Figure 2 : Temp Cycle -40°C to +85°C



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6.0 LOW TEMPERATURE STORAGE

Twenty Five devices have been subjected to Low Temperature Storage at 2000 hours at -40°C.

Results:

The maximum changes in Responsivity after 2000 hours were +6.4% and -2.4%. The monitor current showed maximum changes of +2.5% and -1.9%. These results are shown in Figures 3 and 4.

Conclusion:

The Receiver Module meets the Low Temperature Storage requirements of Bellcore TA-NWT-000983.

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Figure 3 : Low Temperature Storage -40°C

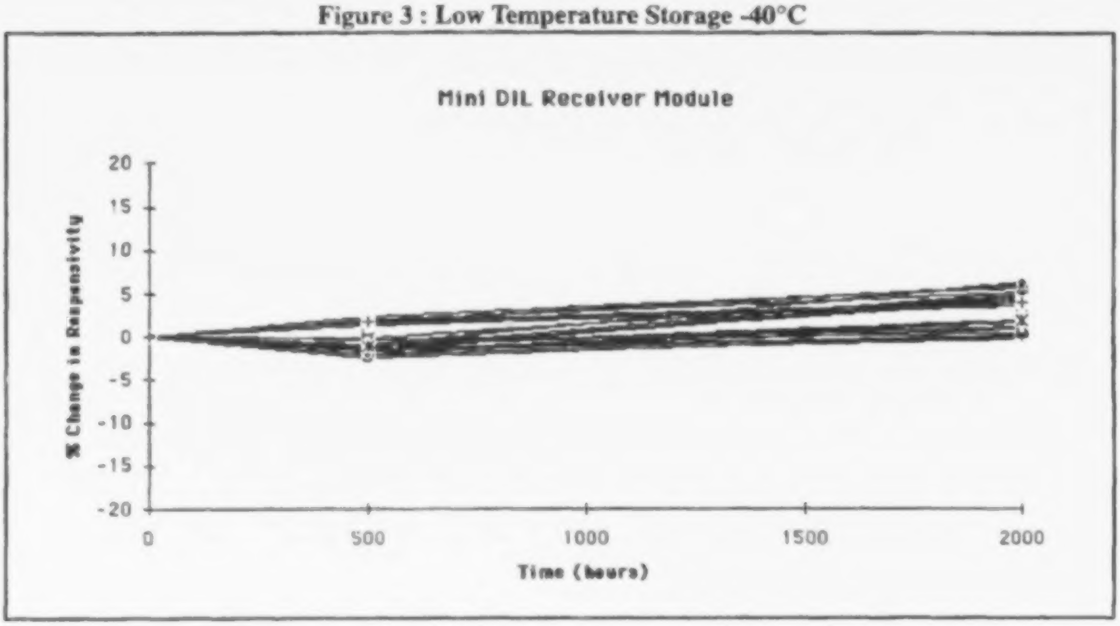
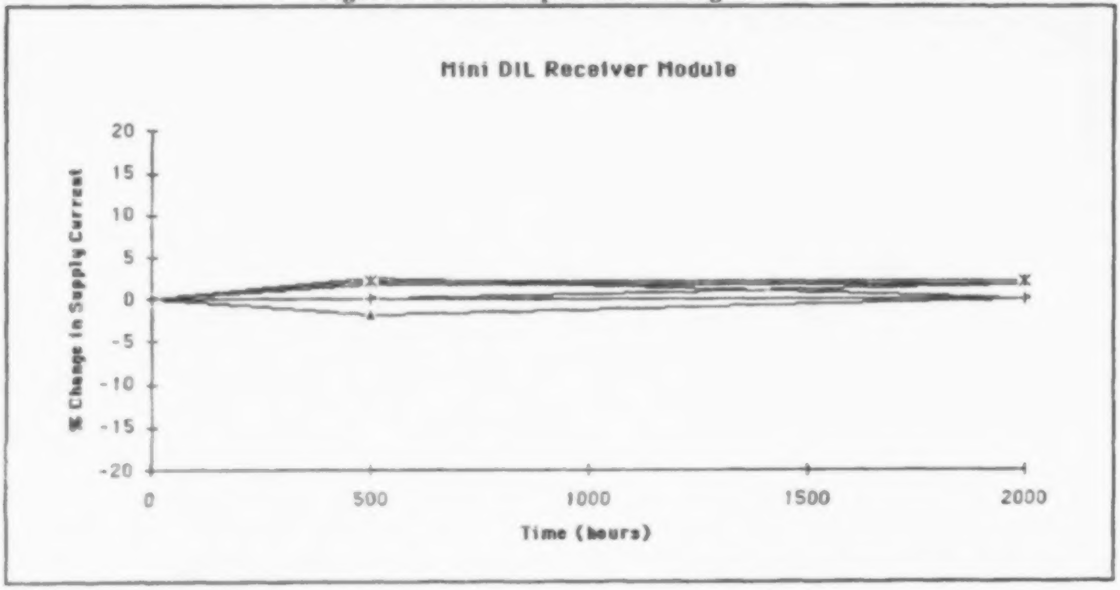


Figure 4 : Low Temperature Storage -40°C



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7.0 HIGH TEMPERATURE STORAGE

Eleven devices have been subjected to the High Temperature Storage test for 5000 hours at +85°C. The Bellcore requirement is 2000 hours.

Results:

Maximum responsivity changes of +5.6% and -4.3% were measured after 5000 hours and graphical data is given in Figure 5. Supply current changes varied between +3.8% and -1.6%, and are given in Figure 6.

Conclusion:

The Receiver Module meets the High Temperature Storage requirements of Bellcore TA-NWT-000983.

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Figure 5 : High Temperature Storage 85°C

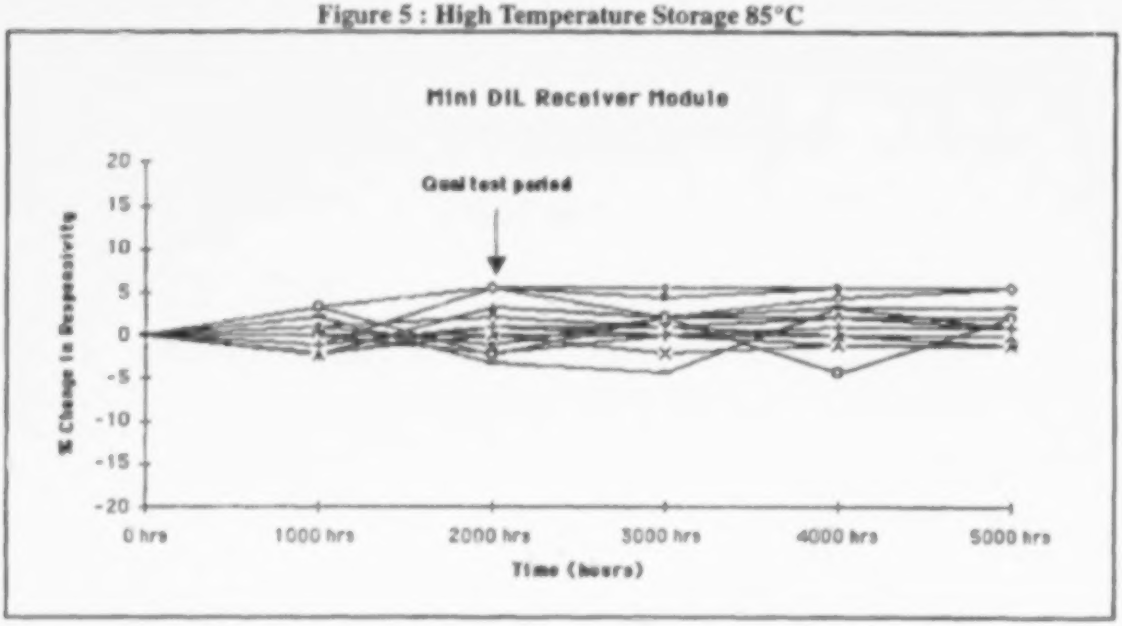
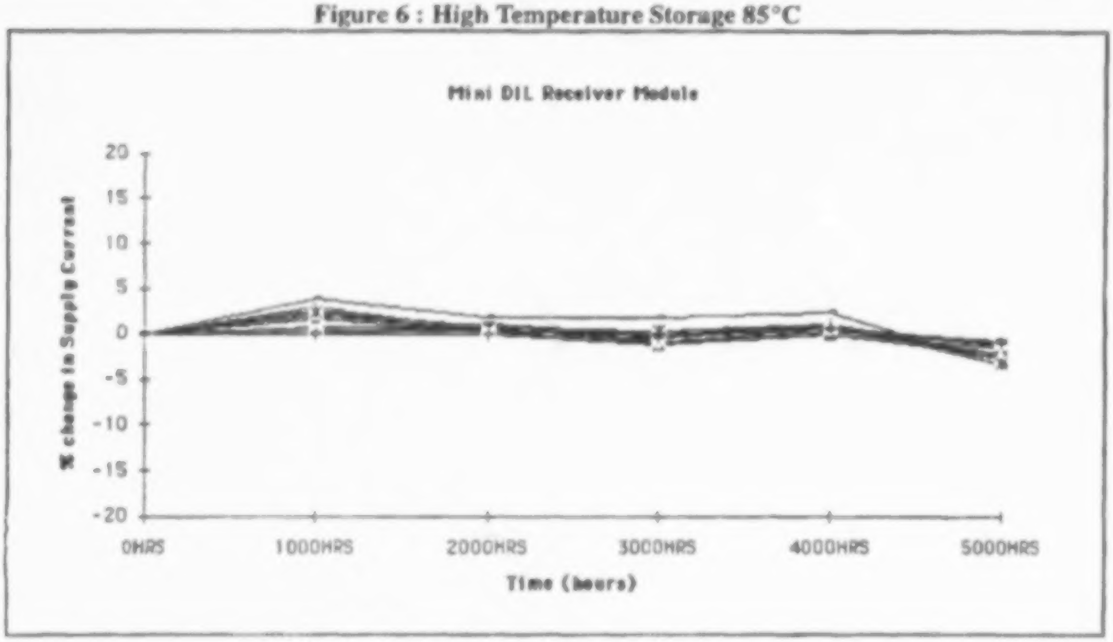


Figure 6 : High Temperature Storage 85°C



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8.0 CYCLIC MOISTURE RESISTANCE

Eleven modules have completed twenty cycles of the moisture resistance test as required by Bellcore 983 for uncontrolled environments followed by Fibre Pull 1Kg, 3 times for 10 seconds.

Results:

A Maximum responsivity change of -4% and supply current changes varying between +3% and -1% were measured after 20 cycles. The data is shown graphically in Figures 7 and 8.

Conclusions:

The Receiver Module meets the Cyclic Moisture Resistance requirements of Bellcore 983.

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Figure 7 : Cyclic Moisture Resistance

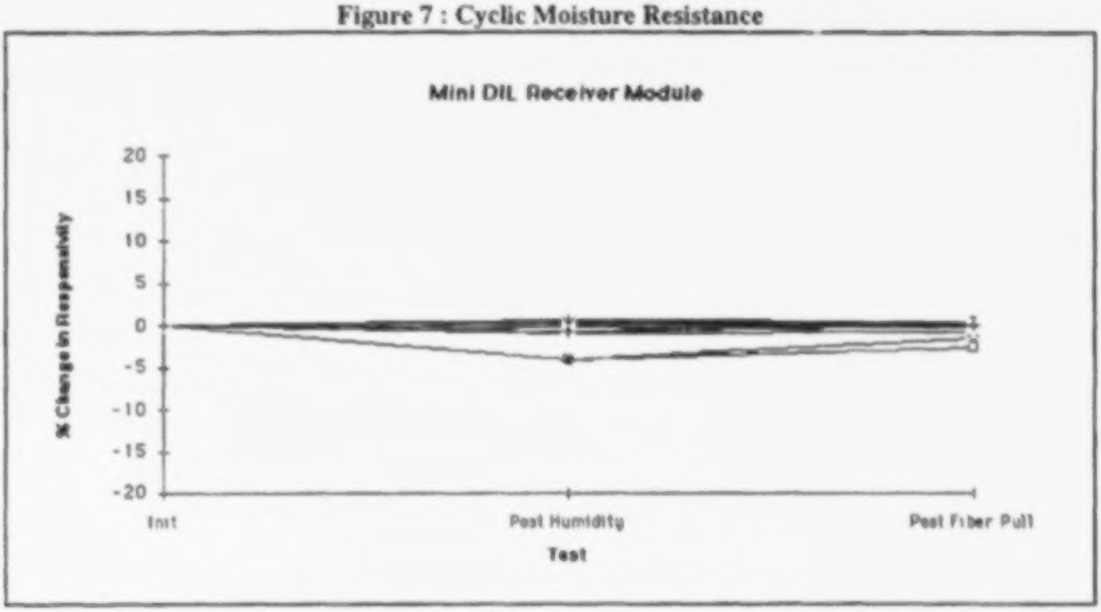
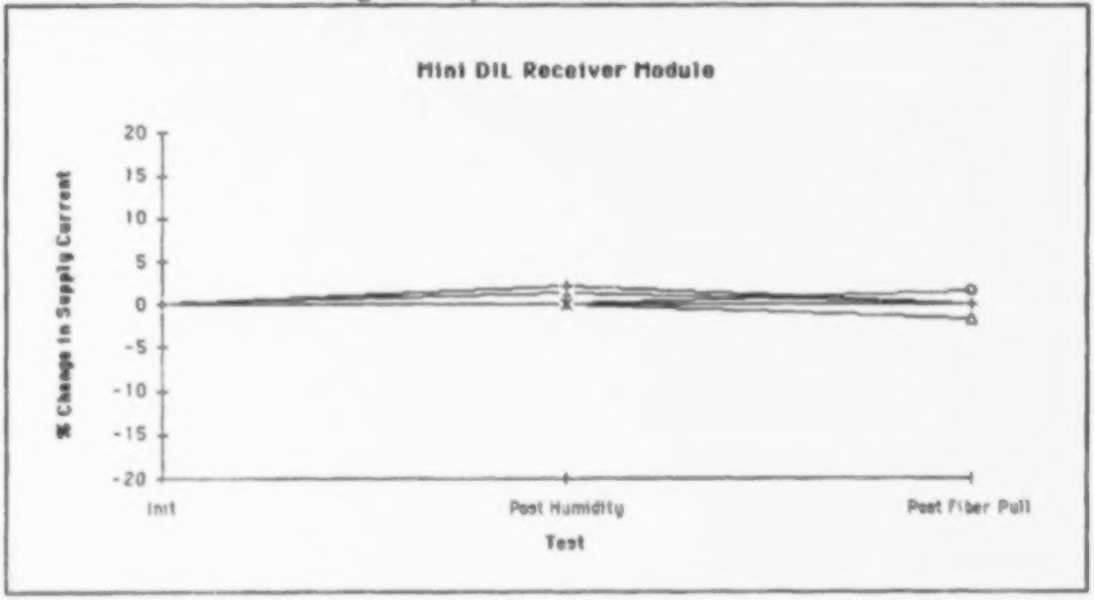


Figure 8 : Cyclic Moisture Resistance



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9.0 MECHANICAL INTEGRITY

Fibre Pull, Mechanical Shock and Vibration tests were performed sequentially using the same samples. Results for all three tests are shown in graphical form in Figures 9 and 10.

Fibre Pull

1Kg, 3x, 10 seconds

Pre and Post electro-optical measurements were performed on the devices subjected to a fibre pull of 1kg, 3 times for a minimum duration of 10 seconds, in a direction coaxial with the fibre as it exits the module package. The maximum change in responsivity of 1.8% demonstrates the effectiveness of the fibre retention design to withstand external forces applied to the fibre pigtail.

Mechanical Shock

MIL-STD-883, Method 2002, Condition B, 1500g, 0.5ms, 5 times / axis. (These devices have been tested to the more severe 1500g objective of Bellcore rather than the 500g requirement.)

Each of the eleven samples were subjected to five shock pulses of 1500g, 0.5ms duration in each of the three orthogonal axes and in both directions - a total of 30 shocks.

Maximum changes in responsivity were +3% and -3% and in supply current were +2% and -2%. These changes underwrite the inherent integrity of the mechanical structure of the module and demonstrates conformance to the Bellcore document.

Vibration

MIL-STD-883, Method 2007, Condition A, 20g, 20-2000Hz, 4 min/cycle, 4 cycle/axis

Maximum changes in responsivity over the leg were +4% and -1% and the change in supply current was -1%. These changes underwrite the inherent integrity of the mechanical structure of the module and demonstrates conformance to the Bellcore document.

Conclusion:

The Receiver Module meets the Bellcore TA-NWT-000983 requirements for Fibre Pull, Mechanical Shock and Vibration testing.

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Figure 9 : Mechanical Integrity

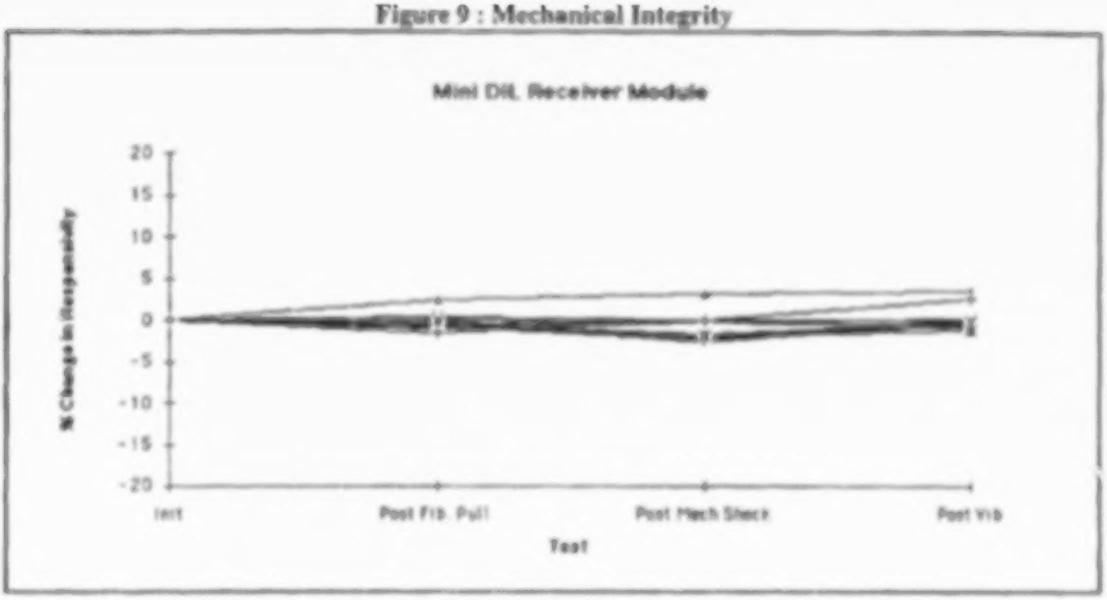
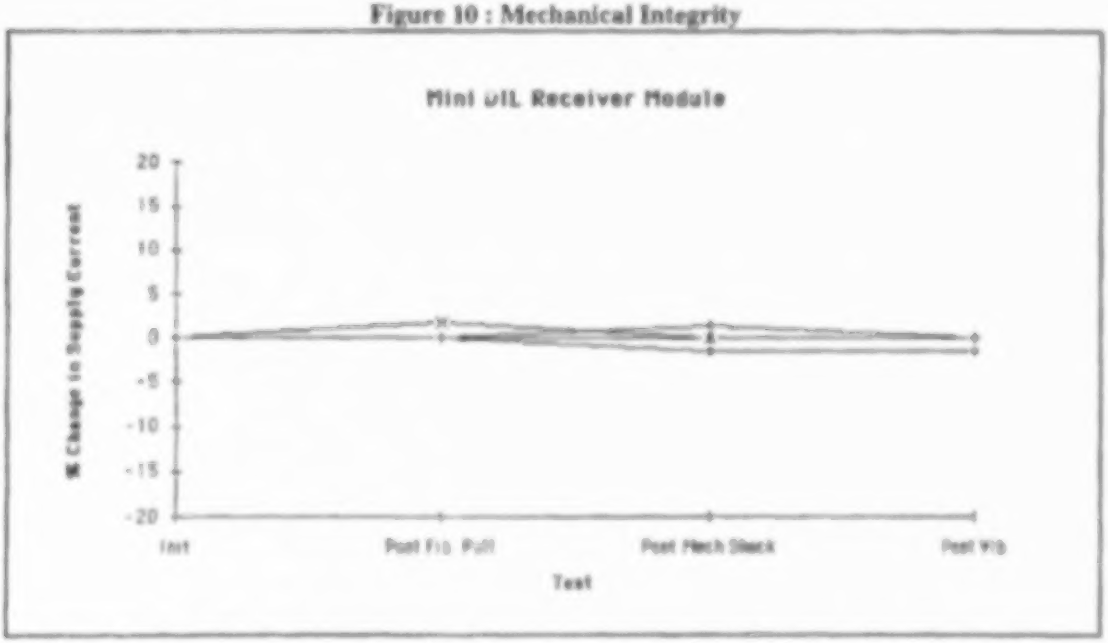


Figure 10 : Mechanical Integrity



10.0 SOLDERABILITY, THERMAL SHOCK AND LEAD INTEGRITY

Solderability, Thermal Shock and Lead Integrity tests were performed sequentially using the same samples. The hermeticity of the devices was measured pre-test, and after the Thermal Shock and Lead Integrity legs.

SOLDERABILITY

Tests were conducted in accordance with MIL-STD-883 method 2003, with:-

No Steam Ageing

Type R Flux

60/40 tin lead solder

Solder temperature 230°C

10x magnification visual examination

Results:

All the leads had at least 95% coverage of solder coating which meets the requirements of the specification.

THERMAL SHOCK - LIQUID TO LIQUID

Eleven devices were subjected to MIL-STD-883, Method 1011, Condition A, non-operating. The temperature extremes were 0°C and 100°C, the devices were transferred between these extremes 15 times with a transfer time of less than 10 seconds.

Results:

All units met the hermeticity limits defined in the detail specification for the product - see the table of results below.

LEAD INTEGRITY

Eleven devices were subjected to MIL-STD-883, Method 2004, Conditions A, B1 and B2.

Results:

All units met the hermeticity limits defined in the detail specification for the product - see the table of results below.

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Serial Numbers	Pre Mech. Leg.	Post thermal shock	Post Lead Integrity
X10873.02	3E-9	4E-9	4E-9
X10873.04	4E-9	1E-8	5E-9
X10873.03	4E-9	1E-8	5E-9
CC32606.05	2E-9	2E-9	4E-9
X10873.09	2E-9	2E-9	3E-9
X10873.06	2E-9	1E-9	2E-9
CC33079.08	3E-9	4E-9	3E-9
CC33079.07	2E-9	4E-9	3E-9
CC33079.04	4E-9	1E-8	1E-8
CC33079.01	4E-9	6E-9	4E-9
CC33079.02	2E-9	4E-9	2E-9

* Hermeticity post test - Leak rate shall not to exceed 1x10-8 atm. cc/s He.

Conclusion:

The Receiver Module meets the Solderability and Thermal Shock requirements of Bellcore TA-NWT-000983 and an additional lead integrity test to MIL-STD-883 Method 2004.

Additional Tests:

In addition to the module related Solderability and Thermal Shock tests specified, the package has also satisfactorily undergone a separate hermetic qualification programme conducted to Nortel's own corporate standards. This programme includes an assessment of hermeticity after being subjected to the following tests:-

- Lead Integrity (Tension and Stress)
- Resistance to Soldering Heat/Thermal Shock* (MIL883 Method1011 Cond. [illegible])
- Temperature Cycling* (MIL883 Method1010 Cond. C)
- Humidity (MIL202 Method103 70°C 85% RH)

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11.0 INTERNAL MOISTURE

Modules were tested by the mass spectrometer technique as defined in procedure 1 of MIL-STD-883, Method 1018. The maximum allowable water vapour content is 5000ppm.

Results:

The mean moisture content on a sample of 11 devices was 650ppm and the standard deviation was 400ppm. This demonstrates the stringent level of piecepart and material control, and the high standard of cleanliness which is inherent in Nortel's manufacturing processes.

Conclusion:

The Receiver Module meets the Internal Moisture requirements of Bellcore TA-NWT-000983.

12.0 FLAMMABILITY

Analysis has been completed and detailed below.

Reference specification: TR-NWT-000078
TR-TSY-000357

Requirements: To determine the oxygen index rating of associated combustible materials of the full device as used by the customer. Materials shall have an oxygen index of greater than 28%. Any materials failing to meet this requirement should be reported.

Results:

Materials:-

1. Singlemode Hytrel secondary coated fibre. The oxygen index of this material is of the order of 21%. The material has been subjected to the needle flame test and will sustain a flame. (report THR/94/135).

2. Santoprene 251/80 silicon free Protective boot. UL 94 flame rating 1.39mm V-0, LOI 25%. Data supplied by Advanced Elastomer Systems product data sheet for Santoprene 251/80 thermoplastic rubber.

Conclusion:

The flammability of the external components of the device are confined to the fibre and its associated components and are listed above in line with the requirements of the controlling documentation. The volume of this material is very small compared to the volume content of the expected system into which the device is mounted. As this material is not concentrated in one area, (since the fibre should not be coiled tighter than a radius of 30mm) it is considered to be suitable for use.

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13.0 ESD

Six devices were separately subjected to forward and reverse applications of Electrostatic Discharge according to the Human Body Model defined in MIL-STD-883 Method 3015.3 (NPS25268, Section 4.5.3). To establish the threshold level, device failure was defined as one or more of the following:-

(i) 10% change in parametric performance for Responsivity, Output Voltage or Current.

(ii) PIN dark current >5nA.

6 devices were tested from 200 volts to 2000 volts in various increments:

All devices exceeded the 500 Volt minimum requirement.

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14.0 CONCLUSIONS

This report has presented the qualification programme test results for the PTAV50/155/622 series of Mini DIL Receiver Modules, and demonstrates that the device meets the Qualification Test requirements of Bellcore TA-NWT-000983, "Reliability Assurance Practices for Optoelectronic Devices in Loop Applications".

The results observed in this report reflect the high stability of the optical train in maintaining coupling efficiency throughout the duration of the stringent Bellcore mechanical, environmental and endurance tests. The inherent long-term reliability of the module has been demonstrated from the Accelerated Ageing data.

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APPENDIX 1: Damp Heat Test

The Damp Heat test was carried out on the Mini DIL Laser Module and these results are read across to the Receiver Module due to the structural similarity of the devices. The external construction of the laser and receiver is the same as is the method of fibre aligning internal to the package.

Thirteen devices were tested at 40°C and 95% RH for 56 days. The mini DIL has no epoxy in the non-hermetic portion of the module and this test was carried out for information only.

Results:

The maximum changes seen in forward current were +5% and -1%. The Monitor current showed maximum changes of +6% and -3%. This data is set out graphically in Figures 11 and 12.

Conclusion:

The parameters measured were within the limits of ± 10%.

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Figure 11 : Damp Heat Test

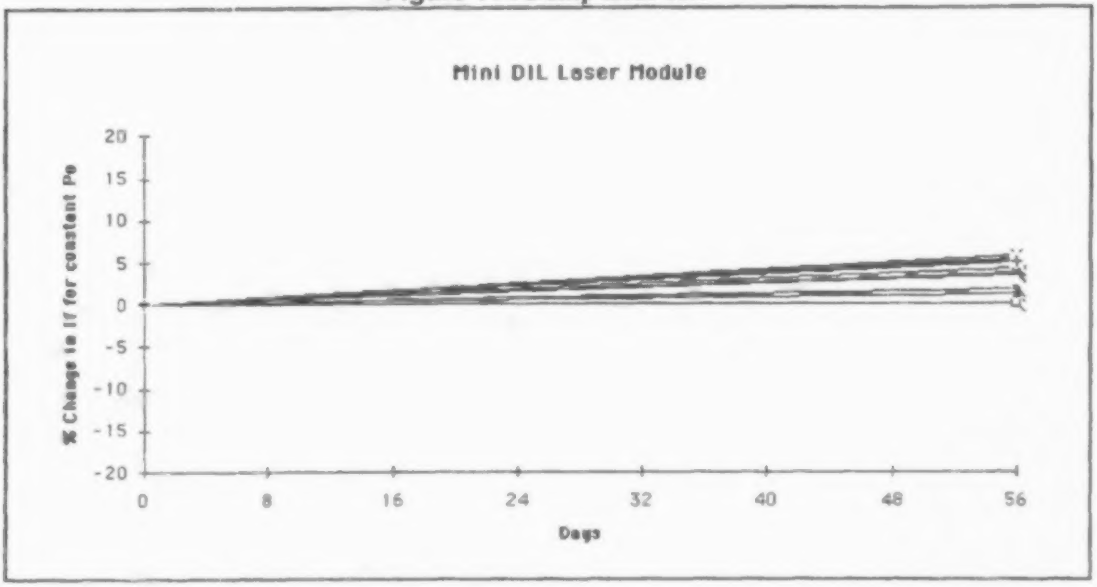
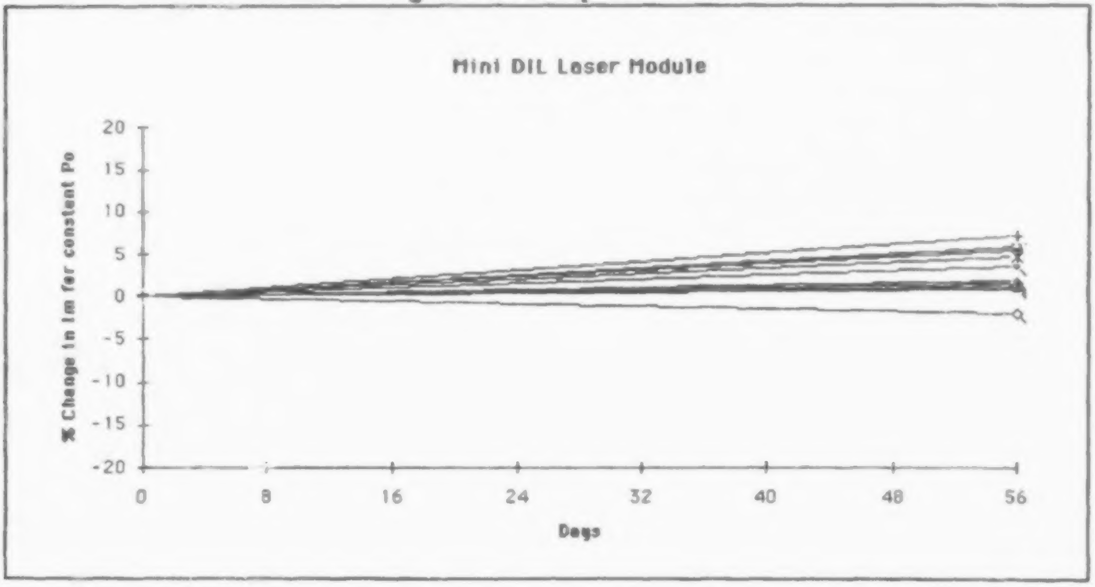


Figure 12 : Damp Heat Test



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HEWLETT PACKARD

1300 nm Fiber Optic Transmitter and Receiver

Reliability Data

HFBR-1312T, 2316T

Introduction
Hewlett-Packard's organization-wide quality system includes an ongoing reliability monitor program. Reliability monitors generate a statistical quality control data base from which these reliability data sheets are published. A material review board reviews real-time product quality/reliability performance and implements appropriate corrective action. Our modern failure analysis capability is a key tool in this process.

Prior to their introduction in May of 1993, the HFBR-1312T transmitter and HFBR-2316T receiver were extensively tested for quality and reliability. The reliability data contained in the subsequent pages serves to validate the integrity of the HFBR-0300 Series components. With HP's dedication to continuous improvements aimed at perfection, the HFBR-0300 Series quality and reliability are expected to continue to improve.

Transmitter Reliability
Hewlett-Packard's HFBR-0300 Series fiber optic transmitters and receivers have been designed with reliability in mind. The HFBR-1312T transmitters incorporate an efficient AlGaAsP emitter and an optical lens system. This design allows the HFBR-1312T transmitters to be driven at relatively low average current levels for a specified amount of coupled power into the fiber. Because failure rates increase with transmitter forward currents, a low average current translates into excellent transmitter reliability.

Reliability Prediction Model
The reliability prediction model used is based upon the exponential failure rate coupled with the Arrhenius temperature de-rating equation (assumes constant failure rate in time and no failure mechanism change between stress and use conditions). HP's conservative analysis includes infant mortality failures. A conservative activation energy of 0.43 eV is taken from MIL-HDBD-217 for Hybrid devices. It is used for temperature de-rating coupled with the Arrhenius equation. Confidence intervals are based upon the chi-squared prediction method.

HEWLETT PACKARD

1300 nm Fiber Optic Transmitter

Reliability Data

HFBR-1312T

High Temperature Operating Life Test

A. Demonstrated Performance

Test	Test Condition	Samples	Device Hours	Failures
HTOL	$T_A = 150°C$, $I_F = 100$ mA	180 units	555,385	1

B. Failure Criteria

Product failure has occurred when the unit fails catastrophically or when light output power decreases 3 dB.

C. Failure Mode

The single failure was a catastrophic electrical open.

D. Failure Rate Prediction

I_F @ 100 mA				
Ambient Temperature (°C)	MTTF (DC Stress Conditions)		FIT Failure Rate [3] (DC Stress Conditions)	
	Point [1]	90% CI [2]	Point [3]	90% CI [2]
150	555,000	143,000	1,800	7,000
85	3,233,000	831,000	309	1,200
80	3,793,000	975,000	264	1,030
75	4,468,000	1,149,000	224	871
70	5,286,000	1,359,000	189	736
65	6,281,000	1,615,000	159	619
60	7,498,000	1,927,000	133	519
55	8,993,000	2,312,000	111	433
50	10,842,000	2,787,000	92	359
45	13,139,000	3,378,000	76	296
40	16,009,000	4,115,000	62	243
35	19,618,000	5,043,000	51	198
30	24,183,000	6,217,000	41	161
25	29,995,000	7,711,000	33	130

Notes:

1. The point MTTF (representing an estimate of the mean point MTTF) is the total device hours divided by either the number of failures or unity if there are no failures.
2. This MTTF and failure rate represent the minimum level of reliability performance that is expected from 90% of all samples. This confidence interval is based on the statistics of the distribution of failures. The assumed distribution of failures is exponential. This particular distribution is commonly used in describing useful life failures. Refer to MIL-STD-690 for details of this methodology.
3. Failure in Time, or FIT, is equal to the number of failures expected in one billion device hours. 1 FIT = 1 failure per 1,000,000,000 device hours.

HFBR-1312T Mechanical and Environmental Test Data

Test	MIL-STD-883/ Other Reference	Test Conditions	Units Tested	Total Failed
Temperature Cycling	1010 Condition B	-55 to +125°C, 15 minutes dwell, 5 minutes transfer, 1000 cycles	80	0
Thermal Shock	1011 Condition B	-55 to +125°C, 5 minutes dwell, 10 seconds transfer, 20 cycles	30	0
High Temperature Storage	1008 Condition B	T_A = +125°C 1000 hours	40	0
85/85		T_A = 85°C, 85% relative humidity V_R = 1 volts Duration = 1000 hours	29	0
Unbiased Pressure Pot		T_A = 121°C, 100% relative humidity Duration = 168 hours	40	0
Mechanical Shock	2002 Condition B	5 blows each axis, 1500 G, 0.5 msec pulse	30	0
Vibration Variable Frequency	2007 Condition A	50 G, 20 to 2000 Hz 4, 4 minute cycles each X, Y, Z	30	0
Port Wear Test	T_A = 25°C	500 disconnects and reconnects Less than 1 dB LOP variation	10	0
Connector Side Load Test[1]	T_A = 25°C	1 Kg side load force, applied and released <1 dB LOP variation after force is released	10	0
Port Strength	T_A = 25°C	4.6 Kg-cm torque No port damage	10	0
Wave Solderability		Three cycles Flux/Preheat (40 seconds @ 260°C) Solder wave (2 seconds @ 470°C) Cleaning (5 min hot DI water, Oven Dry)	28	0
Chemical Resistance[2]	2015	5 minute soak in Solvents A, B, C, D, acetone, and boiling water	4 per chemical	0
Resistance to Solvents	2015	3, 1 minute immersions, brush after solvent	20	0
ESD	3015	1 kV	9	0

Notes:

1. The Connector Side Load test required that the housing be held so as to prevent the leads from yielding. The load was applied through an ST connectored fiber optic cable, perpendicular to the port. The product family is designed to limit cable and ferrule damage due to cable loading. The support and active leads should yield before damage to the cable or connector occurs. If extreme mechanical abuse of the cable or connector is anticipated, please contact HP's Application Department for suggestions about mechanical strain relief. Due to the spring loaded feature of the ST connector, HFBR-0300 ST products will experience 1 dBm coupled power variation at a side load of less than 1 kg.
2. Solvents from MIL-STD-883, Test Method 2015 are:

   A = a mixture of one part by volume of isopropyl alcohol, and three parts by volume of mineral spirits.

   B = a terpene base solvent consisting of greater than 60% Limonene, heated to 32°C.

   C = 1-1-1 Trichloroethane.

   D = a mixture of 42 parts by volume of DI water, 1 part by volume of propylene glycol monomethyl ether, and 1 part by volume of monoethanolamine; heated to 63°C.

HEWLETT PACKARD

1300 nm Fiber Optic Receiver

Reliability Data

HFBR-2316T

High Temperature Operating Life Test

A. Demonstrated Performance

Test	Test Condition	Samples	Device Hours	Failures
HTOL	$T_A = 100°C$, $V_{CC} = 5.0$ V	100 units	100,000	0

B. Failure Criteria

Product failure has occurred when the unit fails catastrophically.

C. Failure Mode

There were no product failures.

D. Failure Rate Prediction

Ambient Temperature (°C)	MTTF		FIT Failure Rate [3]	
	Point [1]	90% CI [2]	Point [1]	90% CI [2]
100	100,000	43,000	10,000	23,050
85	166,000	72,000	6,039	13,921
80	198,000	86,000	5,059	11,661
75	237,000	103,000	4,218	9,722
70	286,000	124,000	3,499	8,064
65	346,000	150,000	2,887	6,654
60	422,000	183,000	2,369	5,461
55	517,000	224,000	1,933	4,457
50	638,000	277,000	1,569	3,615
45	791,000	343,000	1,265	2,915
40	987,000	428,000	1,013	2,335
35	1,241,000	538,000	806	1,858
30	1,271,000	681,000	637	1,468
25	2,003,000	687,000	499	1,151

Notes:

1. The point MTTF (representing an estimate of the mean point MTTF) is the total device hours divided by either the number of failures or unity if there are no failures.
2. This MTTF and failure rate represent the minimum level of reliability performance that is expected from 90% of all samples. This confidence interval is based on the statistics of the distribution of failures. The assumed distribution of failures is exponential. This particular distribution is commonly used in describing useful life failures. Refer to MIL-STD-690 for details of this methodology.
3. Failure in Time, or FIT, is equal to the number of failures expected in one billion device hours. 1 FIT = 1 failure per 1,000,000,000 device hours.

HFBR-2316T Mechanical and Environmental Test Data

Test	MIL-STD-883/ Other Reference	Test Conditions	Units Tested	Total Failed
Temperature Cycling	1010 Condition B	-55 to +125°C, 15 minutes dwell, 5 minutes transfer, 1000 cycles	80	0
Thermal Shock	1011 Condition B	-55 to +125°C, 5 minutes dwell, 10 seconds transfer, 20 cycles	30	0
High Temperature Storage	1008 Condition B	$T_A = +125°C$ 1000 hours	40	0
85/85		$T_A = 85°C$, 85% relative humidity $V_B = 3$ volts Duration = 1000 hours	30	0
Unbiased Pressure Pot		$T_A = 121°C$, 100% relative humidity Duration = 168 hours	40	0
Mechanical Shock	2002 Condition B	5 blows each axis, 1500 G, 0.5 msec. pulse	30	0
Vibration Variable Frequency	2007 Condition A	50 G, 20 to 2000 Hz 4, 4 minute cycles each X, Y, Z	30	0
Port Wear Test	$T_A = 25°C$	500 disconnects and reconnects Less than 1 dB LOP variation	10	0
Connector Side Load Test[1]	$T_A = 25°C$	1 Kg side load force, applied and released <1 dB variation after force is released	10	0
Port Strength	$T_A = 25°C$	4.6 Kg-cm torque No port damage	10	0
Wave Solderability		Three cycles Flux/Preheat (40 seconds @ 260°C) Solder wave (2 seconds @ 470°C) Cleaning (5 min. hot DI water, Oven Dry)	28	0
Chemical Resistance[2]	2015	5 minute soak in Solvents A, B, C, D, acetone, and boiling water	4 per chemical	0
Resistance to Solvents	2015	3, 1 minute immersions, brush after solvent	20	0
ESD	3015	1 kV	9	0

Notes:

1. The Connector Side Load test required that the housing be held so as to prevent the leads from yielding. The load was applied through an ST connectored fiber optic cable, perpendicular to the port. The product family is designed to limit cable and ferrule damage due to cable loading. The support and active leads should yield before damage to the cable or connector occurs. If extreme mechanical abuse of the cable or connector is anticipated, please contact HP's Application Department for suggestions about mechanical strain relief. Due to the spring loaded feature of the ST connector, HFBR-0300 ST products will experience 1 dBm coupled power variation at a side load of less than 1 kg.
2. Solvents from MIL-STD-883, Test Method 2015 are:
   A = a mixture of one part by volume of isopropyl alcohol, and three parts by volume of mineral spirits.
   B = a terpene base solvent consisting of greater than 60% Limonene, heated to 32°C.
   C = 1-1-1 Trichloroethane.
   D = a mixture of 42 parts by volume of DI water, 1 part by volume of propylene glycol monomethyl ether, and 1 part by volume of monoethanolamine, heated to 63°C.

HFBR-0300 Basic Package Material Properties

Property	Test Conditions
Flame Resistance UL Bulletin 94	V-0 at 0.76 mm/5 V at 1.9mm
Oxygen Index	47%
Arc Resistance	ASTM D495
Continuous Use Rating UL	170°C
Glass Transition Temperature	Tg = 215°C
Wave Soldering Capability	Hewlett-Packard Process

Note

The material properties listed are for the outer housing and port assemblies of the HFBR-0300 product family. Tests were performed on the HFBR-0400 product family, which uses the same package materials.

Fibre Optic Component Manufacturers

1. **Force Inc.**
825 Park Street, Christiansburg, Virginia 24073
Tel: 1-800-732-5252
Fax: 540-381-0392
Web: www.forceinc.com
email: sales@forceinc.com
Contact: Anthony (Tony) Rice

2. **LDI (Laser Diode, Inc.)**
2 Olsen Avenue, Edison, New Jersey 08820
Tel: 732-549-9001
Fax: 732-906-1559
Web: www.laserdiode.com
email: sales@laserdiode.com
Contact: Scott Grayman, sgrayman@laserdiode.com

3. **Lucent Technologies**
Web: www.lucent.com/micro/opto
Canadian Distributer: Neutronics Components Ltd.
232 Herzberg Road, Suite 201, Ontario K2K 2A1
Tel: 613-599-1263
Fax: 613-599-4750
Web: www.neutronics.ca
Contact: Jennifer LeDrew, Jennifer@neutronics.ca

4. **Nortel Networks**
8200 Dixie Road, Suite 100, Brampton, Ontario L6T 5P6
Tel: 1-800-466-7835
Web: www.nortelnetworks.com
Contact: Lynn Bearl, bearll@nortelnetworks.com

5. **OCP (Optical Communications Products)**
20961 Knapp Street, Chatsworth, California 91311
Tel: 818-701-0164
Fax: 818-701-1468
Web: www.ocp-inc.com
Contact: Jack Neenan, jneenan@ocp-inc.com

6. **Agilent Semiconductor Products (formerly Hewlett Packard)**
Agilent Technologies (Canada) Ltd.
5150 Spectrum Way, Mississauga, Otario
Tel: 1-800-235-0312
Web: www.semiconductor.agilent.com

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This report provides a selection guide and specification charts for the selectin of fibre optic transmitters and receivers for digital telemetry between the Fibre Optic Array Module (FOAM) and Fibre Optic Receive Unit (FORU) of TIAPS. A total of five fibre optic paths (5 X 62.5/125μm multimode fibre) transmit data from the two receive arrays to receive hardware on the ship. Data rates are expected to be between 25 and 50 Mbps. Selection of appropriate fibre optic transmitters and receivers requires consideration of environmental, electrical, optical, and mechanical specifications of the devices, as well as general system design guidelines for fibre optic telemetry.

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